USDA Forest Service
General Technical Report RM-95

October 1982

Monetary Valuation of Timber, Forage, and Water Yields from Public Forest Lands

Thomas C. Brown,
Rocky Mountain Forest and Range Experiment Station[1]

[1]Headquarters is in Fort Collins in cooperation with Colorado State University.

Contents

Monetary Valuation of Timber, Forage, and Water Yields from Public Forest Lands

Thomas C. Brown

INTRODUCTION: THE RESOURCE ALLOCATION PROBLEM

Forests contribute in numerous ways to human satisfaction. They may provide timber, water, livestock forage, wildlife habitats, recreation opportunities, wilderness, or any combination of these. They also provide services such as the conversion of carbon dioxide to oxygen, the binding of soil, and the regulation of climate. However, any given forest site can only produce one combination of these goods and services at a time. Choice of one combination, or management alternative, requires giving up other alternatives. Thus, forest managers face an allocation problem.

Land management planning (e.g., forest planning) in a multiple use setting is a very complex allocation problem, particularly for public land producing a great variety of products. Land must be allocated to different uses and funds to different management activities. Public land management decisions are typically based on, among other things, a combination of efficiency and equity considerations. An efficient allocation of resources is one which maximizes the net benefit to society, regardless of who gains and who pays. Efficiency is improved if the value of the economy's output is increased for a given amount of resource input. An equitable allocation is based on someone's opinion of who should benefit and who should pay (see Haveman and Weisbrod 1975).

Estimates of the relative importance of the effects of management alternatives are crucial in comparing the efficiency of the alternatives (see Brown 1981). Monetary values, the estimates of importance used in economic analysis, are one source of importance estimates for land management planning.

Under the existing institutional framework some forest products, such as recreation, environmental, and esthetic goods and services, do not generally move through markets and, therefore, do not have market-determined values. Other products, such as sawtimber and pulpwood stumpage, forage, and water runoff, move through the market, although sometimes in an indirect and limited sense. For example, the Forest Service sells stumpage, but often not in a competitive market. The right to use forage for livestock on public land is also sold, but the price is usually determined administratively. Public agencies rarely charge for the water, and downstream users are usually charged prices determined administratively by local governments or water companies. These are commonly called market products or commodities.

This paper is divided into two parts. The objective of Part I is to review what monetary values are and explain how monetary values for stumpage, forage for livestock, and water for downstream use can be derived for use in comparing management alternatives for public land. The objective of Part II is to demonstrate the use of the methods, using central Arizona's stumpage, forage, and water market situation as an example. The paper does not cover how to use monetary values (for instance, in cost-benefit analysis) and only briefly mentions, in Part I, the basic assumptions and theoretical problems underlying the derivation and use of monetary values.

Part I is written for resource managers and analysts with a minimum of training in microeconomic theory, such as one should receive in a standard undergraduate intermediate microeconomics course. It assumes an understanding of such concepts as economic efficiency, competition, marginal cost and marginal revenue, opportunity cost, supply, demand, and externality. Part I is designed to provide readers with sufficient knowledge to understand Part II and, indeed, to attempt similar valuations of their own. Those familiar with the theory may want to proceed directly to Part II.

PART I: THEORETICAL CONSIDERATIONS

BACKGROUND

Money has the unique quality of being the medium of exchange for a great many goods and services, both factors of production and final consumer products. There is no other single scale in our society on which people, by their actions, record the importance they place on a large number of the goods and services. For this reason, monetary values are a convenient source of information about the importance of forest products.

The use of monetary values as measures of social value has its theoretical foundation in the welfare economics notions of efficiency and Pareto optimality (see Baumol 1977, Bator 1957, Graaff 1957, Ferguson 1972, Sassone and Schaffer 1978). Operationally, a purely competitive economy assures an "efficient" (Pareto optimal) allocation of resources. According to standard economic welfare theory, in a purely competitive economy, the profit-seeking activities of producers result, as though guided by an "invisible hand," in an allocation of resources which maximizes the aggregate satisfactions of consumers. A competitive economy tends to equate the price of a good or service with its minimum average cost, indicating that competitive firms use the most efficient technology available to them and charge the lowest price consistent with their production costs. The competitive price system will reallocate resources in response to a change in consumer tastes, technology, or resource supplies so as to maintain allocative efficiency over time.

The competitive paradigm is used throughout this paper. The methods described herein all utilize competitive markets because such markets provide the most appropriate estimates of monetary values for public decision making. It should be mentioned that there are potential reservations with the use of such methods to derive estimates of social value. These concerns fall in three groups, ranging from the purely theoretical to the practical. The first group consists of the basic assumptions of welfare economics. Among these are that individual tastes, or wants, are taken as given and not questioned (this reflects the utilitarian philosophical basis of welfare economics) and that, for all practical purposes, the existing income distribution is accepted as given and proper (see Krutilla 1961, Samuels 1972). The second group of concerns consists of impediments to a purely competitive economy, which render any market measures of value theoretically impure. These include noncompetitive (e.g., monopolistic) markets, market disequilibrium, externalities, and the fact that not all goods (e.g., public goods) are sold in the market place (see any basic microeconomic text, such as Hirshleifer 1980 or Ferguson 1972). The third group consists of the lack of adequate data to employ the methods. The third group will be discussed in the course of explaining and demonstrating use of the methods.

These reservations are mentioned not to disillusion the reader, but rather to place the main body of the paper in a realistic setting. For discussion of the first two groups of concerns the reader is directed to other sources, of which there are many, in the welfare and environmental economics literature, including those cited above.

What Are Monetary Values?

This section contains a brief review of some elementary microeconomic principles. The value of something (a certain amount of some kind of good or service, called a product) to an individual depends on many things—the individual's tastes or preferences, the use to which it is to be put, the amount of the good or service already in the possession of the individual, its quality, and the availability of substitutes, to name a few. The individual's willingness to pay for successive units of a product at any given time depends on such determinants, plus his or her budget constraint. Willingness to pay is a constrained (by income) measure of the value, expressed in monetary terms, of a given product relative to all other products.

An ordinary demand schedule, or curve, for a product represents quantities which are or would be purchased at various prices during some time period, given constant incomes, preferences, and prices of other products. With rare exceptions, the demand schedule is downward sloping, representing the diminishing marginal utility of the product. For example, the demand schedule in figure 1 shows the amounts of apples which an individual would purchase at given

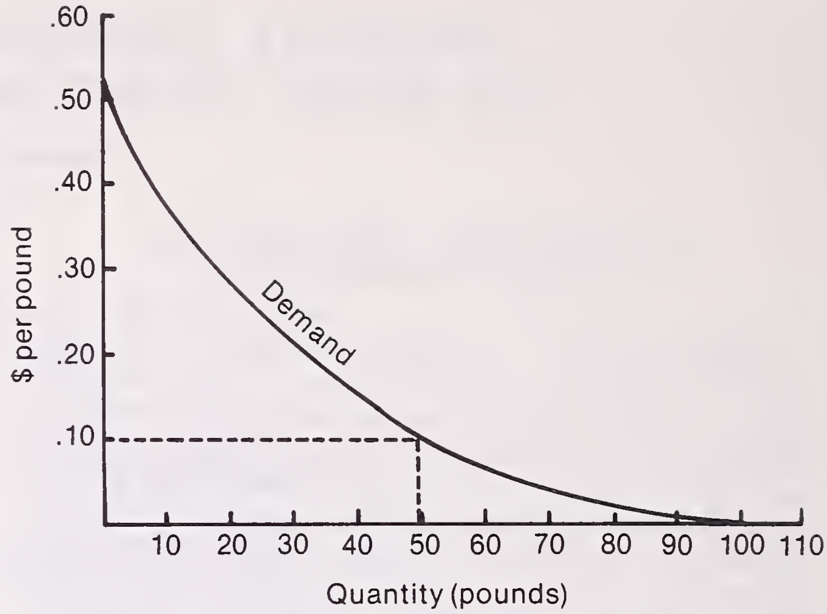

Figure 1.—An individual's demand curve for apples in 1979.

prices. At $0.30 per pound, 20 pounds would be purchased, and at $0.10 per pound, 50 pounds would be purchased. Note, however, that even if apples were free, only 100 pounds would be taken. Also note the marginal nature of the demand schedule: The initial pound of apples has a value to the individual of about $0.53, and each additional pound has a slightly lower value. For example, having 49 pounds, the individual's willingness to pay for the 50th is $0.10. Thus the individual's demand schedule depicts a series of willingnesses to pay values corresponding to a series of quantities.

The horizontal summation of the individual demand curves for the product in a given location is the aggregate, or market, demand curve.[2] For example, the demand curve for apples in some city may be as in figure 2.

Corresponding to the demand curve is a supply curve representing the marginal cost of producing additional quantities of the product and, therefore, the quantities which rationally will be supplied at given prices. The horizontal summation of the firms' supply curves gives the market supply curve. The supply curve is shown to intersect the demand curve at 24,000 pounds in figure 2. The intersection signifies the market price, which is $0.20 per pound in figure 2. Price is the willingness to pay "at the margin," where demand equals supply, and is sometimes called the value in exchange. It is the result of the collective actions of all buyers and sellers who participate in the market economy. The total gross value for the consumers of the 24,000 pounds is given by the area under the demand curve from 0 to 24,000 pounds (about $9,000) and the total cost of supplying the apples is given by the area under the supply curve from 0 to 24,000 pounds (about $3,600).

When 24,000 pounds are bought and sold at $0.20 per pound, a total of $4,800 will change hands, represented by the rectangle enclosed by the dotted

[2]For public goods, where one person's consumption does not diminish another's, as with radio waves, a vertical summation is required.

lines in figure 2. However, consumers derive greater than $4,800 of value. The additional value, represented by the upper shaded area in figure 2 (about $4,200), is the consumers' net value and is called the consumers' surplus.[3] The consumers' surplus exists because all but the last apple exchanged has a value greater than the marginal value. Producers will also benefit from the apple transactions. While $4,800 changes hands, only a portion of that sum was necessary to cover the producers' costs. The residual or producers' net value, called the producers' surplus, is represented by the lower-shaded area in figure 2 (about $1,200). The total net value or surplus is the sum of the consumers' and producers' surpluses ($4,200 + $1,200 = $5,400).

The average gross value of apples to the city's residents is calculated as the total area under the demand curve to the left of the equilibrium point divided by the total quantity consumed ($9,000 ÷ 24,000), or about $0.38. The average net value accounts for supply cost, and is ($9,000 – 3,600) ÷ 24,000, or about $0.23. This is considerably higher than the exchange value of $0.20.

Thus, there is more than one monetary value for a given product in a given location. For our example, there are five total values, a gross expenditure of $4,800, a gross value of $9,000, a consumers' surplus of $4,200, a producers' surplus of $1,200, and a net or combined surplus value of $5,400; and several unit values, including a marginal value (price) of $0.20, an average gross value of $0.38, and an average net value of $0.23. In addition, there are the willingness to pay values of each individual for each quantity of the product.

From the efficiency standpoint, combined surplus (consumers' surplus plus producers' surplus, and hereafter just "surplus") is the appropriate measure of the total monetary value of a product in a given market. Surplus is the appropriate measure for two reasons. First, it gives equal weight to both consumers' benefits and producers' benefits. Second, it is a net value. That is, it is the value to consumers and producers after their respective costs (of purchase for consumers and of production for producers) have been covered, and thus avoids any double counting.

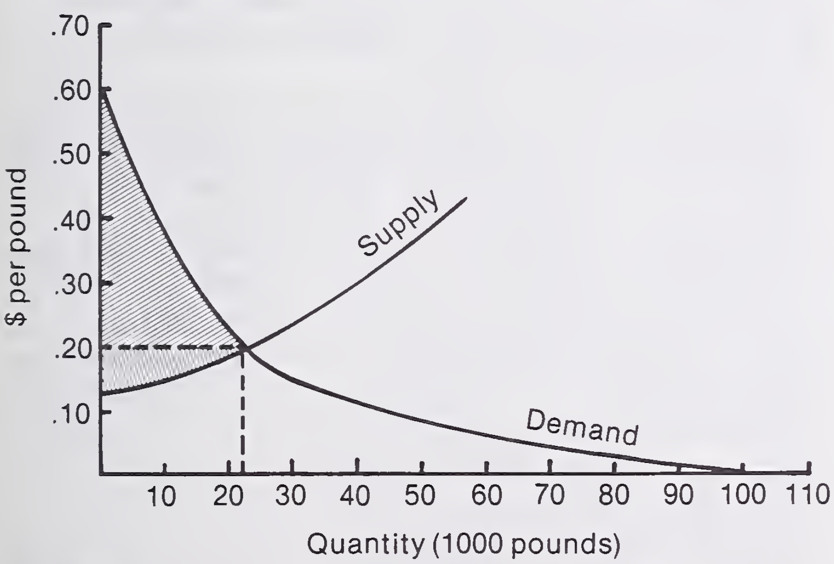

Figure 2.—Hypothetical market demand and supply curves for apples in 1979.

[3]The ordinary demand curve is theoretically incorrect for determining consumers' surplus. The compensated demand curve, which adjusts for the real income changes associated with changes in price, gives the correct surplus measure. However, the compensated demand curve is not observable empirically. Luckily the ordinary demand curve gives a good approximation of the true surplus for most cases (Freeman 1979). The error in using the ordinary demand curve, in any case, is usually minor in light of all other errors in estimating monetary values.

Price is perhaps the most commonly cited example of a monetary value. In fact, "value" is often used in place of price in economics literature. Price is not simply a transformation of a total value, as are the average values. Rather, price focuses on the margin. It is the change in the total gross value with a one unit change in output or, in slightly different terms, the marginal gross value. It is a gross rather than net value because it does not account for production cost. If the price in a market is determined by the intersection of demand and supply (if the market is in equilibrium), there is no surplus (net value) associated with the one unit change. However for markets not in equilibrium, or where supply changes, price is sometimes a very useful base from which to calculate changes in surplus.

Which Monetary Values Are Useful in Public Land Management Planning?

As stated in the previous section, surplus is the correct monetary measure of total value from the efficiency standpoint. If the efficiency effects of alternatives are required as part of a land management planning exercise, measures of surplus are appropriate. However, measures of total surplus are generally unobtainable and often unnecessary for land management planning.

Measures of total surplus are unobtainable because they require demand and supply schedules for all output quantities up to the equilibrium quantity. Such complete schedules are not observable and very difficult to estimate. However, measures of total surplus are unnecessary for land management planning wherever the alternatives under consideration cause only changes in the quantity or quality of products of the land under management. In fact, in most instances, rather small changes in forest product output are being considered. In such cases, the changes in surplus associated with the changes in product output can often be measured directly.

The base from which changes in the quantity and quality of products of the land under management are measured is the "without" alternative. This alternative represents the conditions that are expected to exist in the future if current management direction continues unchanged. The "without" alternative is the "without" situation in the "with and without" framework suggested for use in evaluating water resource projects (U.S. Senate 1962, U.S. Water Resources Council 1973 and 1979) and in evaluating national forest management alternatives (see the Forest Service Manual 1970.8, 1981).

The value of a change in output of a forest product under an alternative other than the "without" alternative is represented by the change in consumers' surplus plus the change in producers' surplus. The total monetary measures and their averages, described above in terms of the apple market, have no role in directly measuring changes in surplus. In appropriate circumstances, however, price plays a major role, especially if it does not change with the change in output. When the price does not change with a change in the output of a forest product, the entire surplus change accrues as a change in producers' surplus, and price in appropriate circumstances is the base from which that change is calculated. When the price changes with a change in the output of a forest product, part or all of the surplus change accrues as consumers' surplus; nevertheless, price can sometimes be used as the base in approximating the surplus change.

When Is Market Price an Appropriate Marginal Value?

Although our economy does not match the purely competitive ideal which assures an economically efficient allocation of resources, many market situations in the economy provide appropriate prices or allow derivation of appropriate prices. "Appropriate" is used in the sense that the prices are estimates of marginal gross value useful in estimating changes in surplus resulting from changes in product output.

While some of these useful market situations include noncompetitive markets (e.g., monopolies), most require competitive markets. The essence of a competitive market is that individual buyers and sellers have no control over product price. A market is considered purely competitive if it has (1) a large number of buyers and sellers (if there are many buyers and sellers acting independently, no one buyer or seller can affect product price by varying the quantity bought or sold); (2) free entry (anyone who wishes to enter or quit the industry must be free to do so); (3) product homogeneity (all units of the product must be very similar—beef is a relatively homogeneous product; perfume is not); and (4) perfect knowledge (all buyers and sellers should be aware of what other buyers and sellers are doing).

The degree to which these conditions are met determines the competitiveness of the market. In the United States, the full range of possibilities exists, from the (nearly) purely competitive such as the lumber, beef, and feed grain markets, to the monopolistic, such as most water and electric power markets.

A product's price is appropriate if the product is sold competitively without market interference; and, in the situation where the product is an input in the production of some secondary product(s), if all such secondary products are also exchanged in competitive markets without interference. We will dissect this sentence by considering the following: (1) what is meant by "sold competitively," (2) what is meant by "without market interference," (3) what happens when the primary product is sold competitively but the secondary product is not, and (4) derivation of an appropriate price when the primary product is not sold competitively but the secondary product is.

If a product is exchanged in a competitive market, there are many sellers and many buyers, as described above. A product "sold competitively" is sold in a market where the buyers' side approaches the competitive market model. Of particular importance is that all buyers are price takers—they have no power to influence the price of the product. However, the seller does not have to be a competitor, and in fact can be a monopolist. For example, if the product is sold to consumers, the price of the product represents the consumers' marginal willingness to pay for the product regardless of whether the seller's side consists of many or only one seller, as long as the product is sold to consumers without market interference. Even if the seller is a monopolist, who restricts production below the level which would be obtained if the product were exchanged in a competitive market, and charges a correspondingly higher price for the product than would be reached in a competitive market, the price still represents the marginal willingness to pay of the consumers in the market. Consumers would be willing to pay that price for a small increase in output of the product. If a public policy somehow caused a unit increase in output of the product, the existing (pre-change) price would represent the gross monetary value of the change.

"Market interference" in the previous two paragraphs refers to either government price controls which interfere with the natural forces of the market, or administrative decisions on the part of the seller(s) to not maximize profits. For details on the impact of price controls on appropriate price, see Sassone and Schaffer (1978), chapter 5. The effects of sellers' nonprofit maximizing goals are difficult to adjust for, even when they can be detected.

When a product is sold competitively without market interference to secondary producers who do not sell their products in competitive markets, the price of the input is inappropriate for valuing a change in its availability, provided the change in input would cause a change in output of the noncompetitive secondary producers. For example, assume a monopolist (that is, on the seller's side) buys the input in question at its competitive price. The appropriate price, or gross unit value, of the input in the production of the monopolist's output is greater than its competitive market price. This is because the input has additional value tied up in the final product. This additional value is reaped as monopoly profit. The appropriate price of the input for this use could only be derived from the price of the final product. Such a derivation is complicated, however, when there are other inputs involved in the production of the monopolist's product, for there is no unequivocally correct way to allocate the monopoly profit among the various inputs. Derivation is further complicated if the product produced from the input is itself an input in the production of a product not exchanged in a competitive market.

If a product is not sold competitively, its price is inappropriate for estimating changes in surplus, unless it by chance approximates the competitive price. A product is not sold competitively if the buyers are so few that they individually, or through collective action, influence the price; or, in the case of products from public land, if the product is sold at an administered price. The competitiveness of purchasers of public timber varies considerably with location. In some situations, there may be only one bidder, who purchases the timber at an appraised price. The purchasers of public forage are usually determined by long-term lease agreements; the grazing fees are administered prices. Water is seldom sold competitively, and usually sold at administered prices. It is often very difficult to determine how close an administered price is to the competitive price.

The appropriate price of a noncompetitively sold input can be derived from the end product price if the end product is a consumer good exchanged in a competitive market without market interference and if all other inputs are sold competitively. It can also be derived from end product price if the end product is itself an input in production as long as the subsequent end products are also exchanged in competitive markets.

METHODS FOR MONETARY VALUATION OF TIMBER, FORAGE, AND WATER

Because of lack of competitive markets and lack of data it is often impossible to assign forest products precise monetary values. Reasonable approximations, however, are generally obtainable without great expense for so-called market products such as timber, forage, and water. This section explains procedures for estimating the value of changes in outputs of those products.

Uncertainty about the effect of numerous necessary assumptions on resultant monetary values naturally gives rise to a range of possible values for any particular situation. Such a range makes sensitivity analysis necessary. In a sensitivity analysis, the relative position of alternatives using the best guess of the value is compared with the relative positions of the alternatives using other possibilities along the range for the value. In many cases, results of a comparison of alternatives will not be significantly affected by varying the value in question within its range. In other cases, where sensitivity analysis shows that the results are sensitive to the value, effort may be necessary to estimate the value more accurately.

The discussion here deals only with cases where timber, forage, and water are beneficial forest products. Thus, increases in output or improvements in quality of the products are beneficial changes, and decreases or impairments are adverse changes. This might not always be the case. For example, increases in runoff might cause flooding. Furthermore, the methods will be described in terms of beneficial changes in these three products. However, the methods and underlying theory apply equally well to beneficial and adverse changes.

Timber, forage, and water have various uses. Timber is used in the production of various wood products, for fuel, as wildlife habitat, for recreation and enjoyment of scenery, for protection of soil from erosion, for production of oxygen, etc. Forage is consumed by livestock and some wildlife species, used to hold soil, adds to the beauty of forest scenes, etc. Water is used to sustain life, for recreation, as fish habitat, for irrigating crops, etc. This paper is about valuation of those uses which can be valued using market-determined prices. Commonly these uses are stumpage for timber, livestock production for forage, and power and downstream consumption for water. Valuation of timber, forage, and water for other uses may employ market price information, but also relies on the use of personal interviews of some sort, and generally requires extensive expertise in economics and statistics.

Step 1 in valuation is to determine whether the change in a forest product is one of quality or quantity or both. **Step 2** is to determine what use or uses of the forest product are affected by the change in quality and/or quantity in the given location. The value of the change depends on the use which is affected. For example, if timber growth increases in some location, will the increased growth be harvested? Or, if forage quality improves, will this improvement allow improved livestock production?

While it may seem elementary that the value of a change in output of a forest product is calculated only in terms of affected uses of the resource, this point is often missed when monetary values are applied to site-specific situations. For example, a small potential increase in pulpwood might be valued at the current pulpwood price. However, it may be that, because of a lack of production capacity, not all the pulpwood currently available for harvest is sold. Clearly an addition to the quantity currently available would have no value, except in the case where the increase was more accessible than some of the pulpwood which would have been harvested in the absence of the increase. In this case, the value would be equal to the harvest cost savings caused by harvesting more accessible pulpwood. Additional examples are the case where additional forage would not be used because of the lack of water developments, and the case where additional water would not be used because of the lack of storage facilities.

The value of an increase in runoff at points of use downstream is sometimes a cause for confusion because it is claimed that water has many downstream uses. Indeed, in many cases water is used for a full range of municipal, industrial, agricultural and recreational uses. The crucial question to be asked is, What use will be affected by the increase? In most cases, the higher-valued uses will have been able to bid water away from lower-valued uses, so that only the lowest-valued existing use (the marginal use) at a given time would use additional water. The value of water in this marginal use is equivalent to competitive market price.

Step 3 in valuation is to decide which forest product changes will be valued, and for which uses those products will be valued. **Step 4** is to choose an appropriate valuation method and apply it.

The available methods which rely on market-determined prices fall into two main groups—those used where the relevant market price is not affected by the change in output and those where the price is affected. The market price will not be significantly affected if the change in output level resulting from the change in quantity or quality of the forest product is small enough relative to the total quantity supplied in the affected market, or if output level is completely unaffected. The market price will be affected if the change in quantity supplied is large enough so that the product will only be purchased at lower prices.

Constant Product Price

The methods described here for valuing changes in timber, forage, or water are further distinguished by whether the forest product or a similar product is sold competitively or, if not, whether it is used in the production of another product which is exchanged in a competitive market and from which the value can be derived.

The Direct Observation of Market Transactions Method

Where the forest product is sold competitively to consumers, or to producers who in turn exchange their end products in competitive markets, where a quantity change is being valued, and where the change is a small enough percentage of the total quantity supplied so as to not affect market price, the market price is a good estimate of the gross unit value of the change. For example, consider figure 3. A horizontal demand curve (D) is used in figure 3 to show that market price is unaffected by changes in the output quantity of the producer in question (here the Ponderosa Forest). The demand curve for the entire industry would of course be downward sloping to the right, as in figure 2, as would the demand curve for an individual producer who represented a sufficiently large portion of the market. Thus the gross unit value of stumpage from the Ponderosa Forest (figure 3) is $0.10 per board foot, regardless of output level.

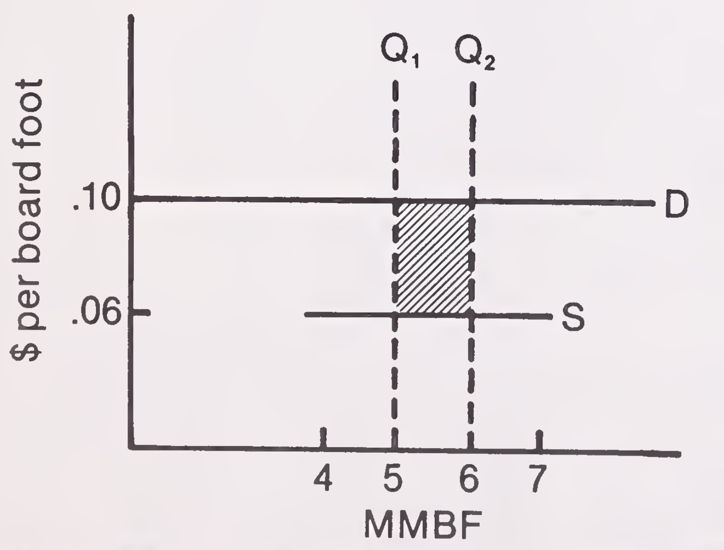

Figure 3.—Demand and supply schedules for ponderosa pine stumpage from the hypothetical ponderosa forest representing the benefit associated with an increase in output.

The horizontal supply curve (S) in figure 3 shows that, at least for volumes from 4 to 7 MMBF per year, the Ponderosa Forest's marginal cost of supplying stumpage is $0.06 per board foot. Current output is constrained at 5 MMBF per year (Q_1) by administrative decision, and continuation of this policy is the "without" alternative. An increase in output to 6 MMBF results in a net benefit (an increase in producer's surplus) of $40,000 per year, represented by the shaded area. The net unit value of this increase is $0.04 per board foot. Note that if the Ponderosa Forest were operating in equilibrium, with marginal cost equal to the stumpage price, there would be no net value to the increase. Note also that if the 5 MMBF per year constraint were not self-imposed, but rather a constraint over which the forest had no control, the supply curve would become vertical at 5 MMBF.

The value of a small increase in timber harvest in an area where buyers of stumpage compete freely for the stumpage could be determined in this manner. One merely needs to know the market price and the marginal cost associated with the change in output. A change in quality, under similar circumstances, could also be valued by observing the difference in existing market prices and costs for stumpage of the two qualities.

Where the forest product is not exchanged in a competitive market, as is often the case with public timber and nearly always the case with forage and water on public lands, the analyst may look for cases where the forest product is exchanged elsewhere in a competitive market. The success of this approach depends on how well the observed market resembles the market which would exist on the public land in question in the absence of institutional constraints. For example, timber stumpage of the same species may be exchanged in a competitive market in another area. Forage on private land is commonly sold for livestock grazing, and rates per animal unit month are reported by the USDA Economics, Statistics, and Cooperatives Service. Water is sometimes sold in markets with several buyers and sellers—the water rental market in the Denver-Fort Collins area is an example (Anderson 1961 and Maass and Anderson 1978).

Basing valuations on markets similar to the one for the resource in question requires great care, for two reasons. First, many market characteristics may be different, including the quality of the forest product, the demand schedule, and the supply schedule. Second, the observed private market may be so heavily influenced by the administered prices of the public forest resource that the market price is biased.

The Cost Savings Method

The cost savings method, and the change in net income which follows, apply where the forest resource being valued is an input in the production of some product, here called the "end product." The cost savings method applies where a change in the forest product input lowers the cost of production of the end product without affecting the level of output or the price of the end product. The cost savings calculated under such conditions is the gross monetary value of the change in the forest product input (the change in the secondary producers' surplus). The net value of the change is calculated by subtracting the costs to the forest of providing the change from the cost savings to the firms using the forest input.

The cost savings method applies only where the output level and price of the end product remain constant, because only then will the cost savings represent the full benefit. If output increased, additional benefits would accrue to the producers (assuming, again, a constant end product price), which would be measured as the net of revenue minus cost for the production increase. Of course, if the benefit from increased output were very small relative to the cost saving on the original output quality, the cost savings method would provide a low but approximate estimate of the benefit. And, if end product price dropped, with constant output level, consumers would benefit, the cost savings would decrease, and again the cost savings would not measure the full benefit. Note that as long as end product output level and price remain constant, it makes no difference what the price is, or whether the demand curve is horizontal or downward sloping (figure 4). It also makes no difference for use of the cost savings method whether the end product is exchanged competitively or not. Note also that this method could also be used to value the change in a forest product which increased production costs, provided the same conditions on end product output level and price were met.

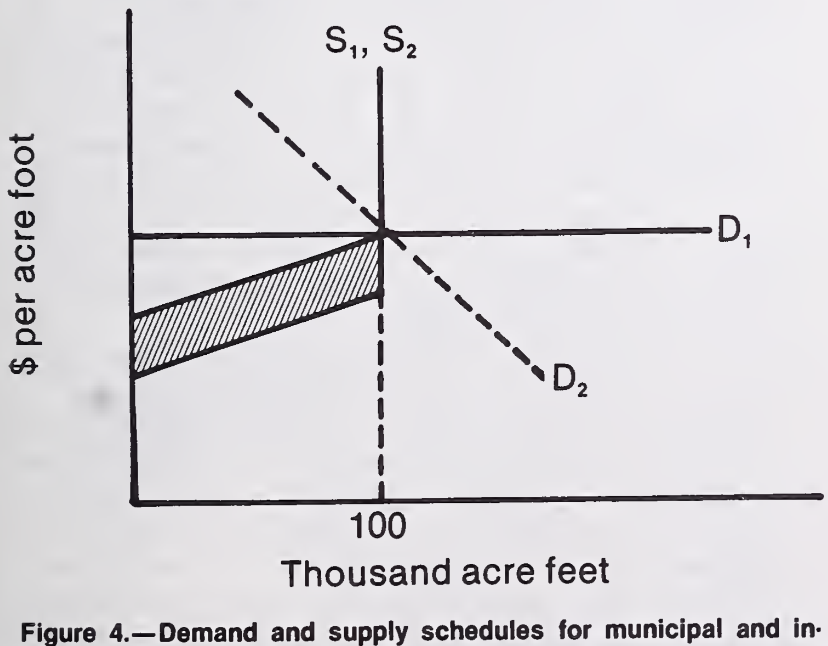

Figure 4.—Demand and supply schedules for municipal and industrial water representing a cost savings from improved quality of streamflow.

The rationale behind the cost savings method is that the cost saved represents inputs which could be used elsewhere in the economy. Using the inputs elsewhere improves the efficiency of resource use. If the cost of these inputs saved is determined competitively, the cost should represent the value to society of the saved inputs. Of course, the prices of the inputs for which the forest product is a substitute must remain constant. If their prices changed with the change in their use caused by the substitution, the cost savings would again not accurately measure the social value of the change in the forest resource.

The cost savings method is most commonly used to value changes in water. The method could be used to value a change in water quality where the change affected water treatment costs without affecting the quantity of water treated. For example, see figure 4, where S_1 and S_2 represent the marginal cost of providing water without and with the runoff quality improvement, respectively. The shaded area represents the cost savings with output constant at 100,000 acre feet.

The vertical portions of the supply curves in figure 4 represent very high costs of supplying more than 100,000 acre feet in either case, as might happen if more water could only be supplied by transporting water from another water basin through very costly canals and pumping stations. Costs are typically depicted by vertical supply curves if they are far too high to be reasonably considered. If the quantity constraint were purely administrative, however, and if marginal costs for quantities above 100,000 acre feet were simple extentions of costs up to that quantity, then the supply curves would be drawn to represent the gradually rising marginal cost past 100,000 acre feet, and the administrative quantity constraint would be represented by a vertical constraint line, as in figure 3. Note, however, that the shape of the supply curves past the fixed quantity is irrelevant for the application of the cost savings method because the method only applies if output is for some reason constrained at its "without" level.

The cost savings method could be used to value a change in quantity of water available for producing hydroelectric power, where additional hydroelectric power replaces more expensive power sources (see Young and Gray 1972 and Brown et al. 1974 for examples). It could also be applied to value a change in water quantity available for agricultural, municipal, or industrial uses, where the additional surface water replaces more expensive pumped water (see Brown et al. 1974 for an example) without affecting the total quantity.

An application of the cost savings method to timber would be to value the use of formerly wasted residues in producing power in a lumbermill where a more costly energy source is currently used. The benefit of the switch to residues is the cost savings. The analyst would, of course, have to account for conversion costs in calculating the cost savings. And, if the residues were formerly not wasted, but used for some other,

lower valued purpose, that value lost is a cost which must be substracted from the cost savings.

The cost savings method might be used to calculate at least part of the value of forage in stabilizing soil. A cost savings of reduced erosion might be a reduction in the cost of downstream reservoir maintenance (dredging and/or reconstruction) (see Boster and Davis 1972 for an example).

The Change in Net Income Method

The change in net income method applies where the forest product is used in the production of a product which is exchanged in a relatively competitive market. The analyst measures the change in net income of firms which are affected by the change in a forest product input. For example, an increase in forage may allow affected ranchers to graze more cattle, yielding an increase in the ranchers' income. The change in net income of the affected firms is the gross monetary value of the change in input of the forest product or, in other words, the change in the secondary producers' surplus. The net value of the change (the net change in surplus) is calculated by subtracting from the gross value the costs to the forest of providing the change. Unlike the cost savings method, end product output is expected to change as a result of the change in the forest product,[4] and the end product must be sold competitively.

The change in net income is calculated without including the monetary cost of the forest product input in question (the stumpage fee or grazing fee or water charge, if any). That is, the cost of the forest product input is not included in the set of costs subtracted from the producer's gross income to calculate the change in net income. Including this cost would interfere with the purpose of the exercise, to calculate the true monetary value of the input. Note, however, that in using the cost savings method, including the input cost does not affect the calculation of the cost savings unless that cost changes with the change in the input.

Three conditions, in addition to the end product being exchanged in a competitive market, must be met for use of the change in net income method. The first is that the producers' inputs, other than the one being valued, must be sold competitively. Only if this is true can the costs of those inputs be assumed to represent their real cost to society. The second condition is that the price of the end product must not change with the change in forest product quantity or quality. The change in net income is the full benefit if the affected firms capture the full benefit—that is, if the entire benefit is producers' surplus. This is only the case where the change in output which causes the change in firms' income does not affect the price of the end product. The third condition is that any products made from the end product (the product which uses the forest product as an input) must in turn be exchanged in competitive markets.

[4]*Unlike the approach here, some authors categorize the cost savings method as a special case of the change in net income method.*

The nature of the change in net income, and therefore its measurement, depends on the change in the forest product and the situation of the affected firms. There are at least three types of situations which would lead to a change in net income that is measurable using the change in net income method:

1. An increase in the quantity of a forest product which provides additional inputs to firms whose level of output was constrained by limited quantities of the input. The increase in quantity of the input supplied would allow increased production without changing the costs of producing the original (prechange) quantity of end product. For example, assume that opening up a virgin area of the Ponderosa Forest for harvest provides stumpage for production of lumber over and above that available on a regular basis from traditional Ponderosa Forest harvest areas, and that the additional harvesting and milling by firms in the area does not affect their costs of harvesting and milling stumpage from traditional harvest areas. The additional stumpage would increase lumber producers' income as long as the additional costs were lower than the additional revenues. Assume that *D* in figure 5 is the demand curve for lumber of a given grade faced by the lumber firms which purchase stumpage from the Ponderosa Forest, and that S_1 is the supply curve of the firms representing their marginal costs of collectively supplying 5 MMBF of lumber net of stumpage cost. The vertical portions of the supply curves represent the high cost of transporting stumpage from other forests, which are too far away to be viable sources of supply. If harvest in the virgin area allows an additional 1 MMBF of lumber to be produced per year, a total of 6 MMBF would be produced. Because marginal cost is constant over the increase (depicted by the horizontal portion of supply curve S_2 for that range of output), the gross value of the increase in harvest (the change in net income) is simply the end product price ($0.50) minus the marginal cost ($0.40) times the increase in output (1 MMBF). If harvest in the virgin area allows an annual harvest of 8 MMBF per year (S_3), the change in net income is the entire shaded area in figure 5. The firms collectively will not produce more than 7 MMBF per year because that is the point where the cost of producing an additional unit of output just equals the return from the additional unit, in the short run. Of course, in the long run, firms could change their plants to produce more stumpage, or new plants could be built.
2. An improvement in the quality or quantity of a forest product input that reduces production costs, increasing the net income of producers through a cost savings on the original quantity of output and an increase in output. For example, an improvement in irrigation water quality could reduce irrigation costs (represented by the shift from S_1 to S_2 in figure 6) yielding a cost savings on the original output quantity (area *abde*), and allow increased output because of the drop in production costs, yielding additional

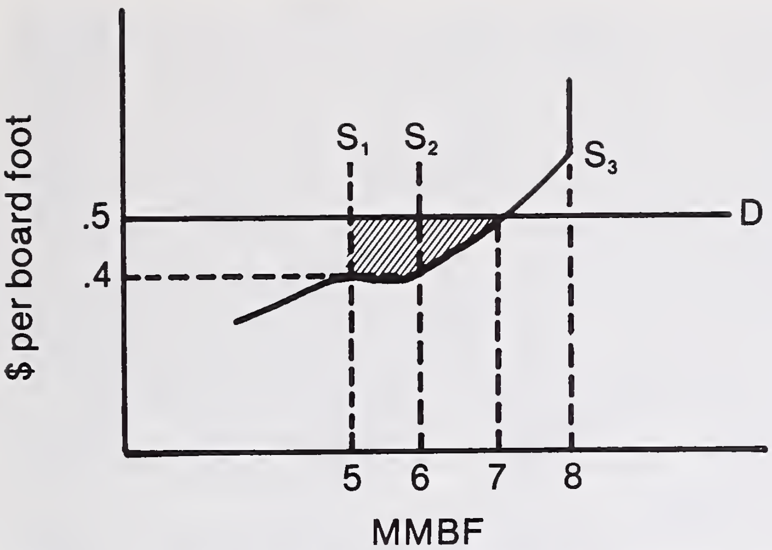

Figure 5.—Demand and supply schedules for ponderosa pine lumber from affected firms representing a change in net income with constant supply schedule.

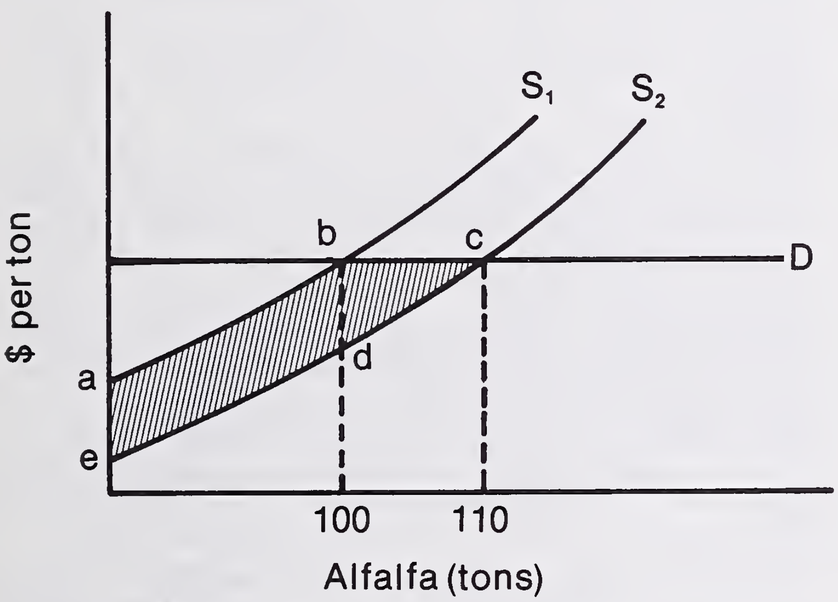

Figure 6.—Demand and supply schedules for affected farms representing a change in net income with a change in supply schedules.

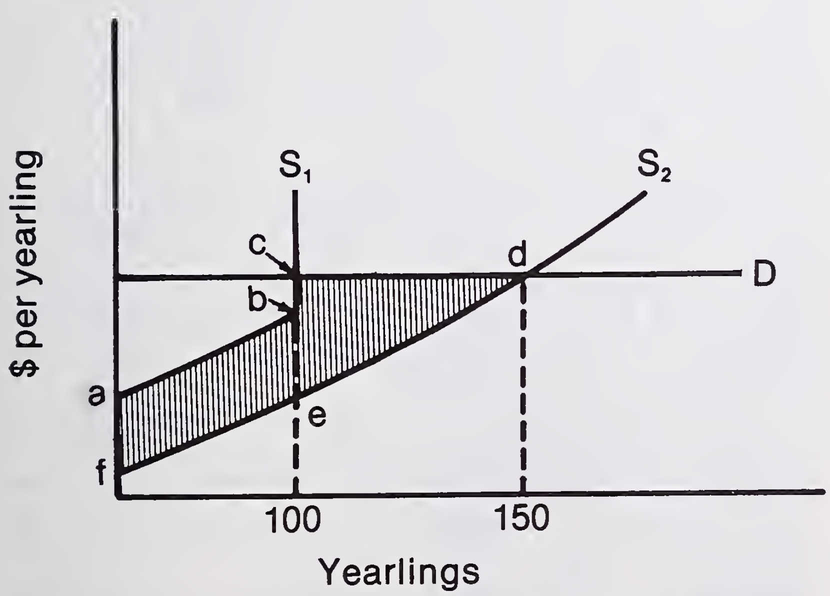

Figure 7.—Demand and supply schedules for a ranch representing a change in net income with increase in available forage.

net income (area *bcd*). The entire change in net income would then be the sum of these two areas (shaded in figure 6).

3. A combination of situations one and two: A change in a forest product input, the availability of which was previously limited so as to constrain production, lowers production costs and eliminates the constraint on production. This may produce a combination of cost savings, production increases caused by the production cost decreases, and production increases caused solely by the increased input availability. For example, suppose that a rancher with an allotment for grazing cattle on public land is currently producing 100 yearlings per year, but could produce more given his capital structure if there were sufficient forage on the range. Reduction of the timber overstory might lower costs of production for the original herd by allowing greater animal weight gains per quantity of forage consumed, because the livestock would not have to use as much energy finding forage (shown as the cost savings *abef*, figure 7), plus allow additional cattle to be grazed, further increasing income (area *bcde*). The entire change in net income is the shaded area in figure 7.

The change in net income is the change in total revenue minus the change in total cost (net of forest product input cost) for the firm or firms affected by some change in the quantity or quality of the input. As long as the price of the end product does not change, the unit change in revenue is the end product market price, and the change in total revenue is the market price times the change in output for the affected firms. Where several firms are affected, the total change in output would be the sum of the changes of the affected firms.

Comparability

There is a problem of comparability between the observation method and the change in net income method if the costs of the producers using the forest product do not reflect an equilibrium situation (a situation where marginal cost equals end product price). Consider the example of stumpage used to produce lumber. With the observation method, the unit change in producers' surplus of a small change in stumpage output (ΔPS_1) is calculated as

$$\Delta PS_1 = P_s - MC_s$$

where P_s is the competitive stumpage price and MC_s is the affected forest's marginal cost of providing stumpage. With the change in net income method, the unit change in producers' surplus of a small change in stumpage output (ΔPS_2) is calculated as

$$\Delta PS_2 = P_\ell - MC_\ell + P_s - MC_s$$

where P_ℓ is the competitive lumber price and MC_ℓ is the marginal cost of producing lumber of the affected firm(s). $MC_\ell - P_s$ is the marginal cost of producing lumber net of stumpage cost. If P_ℓ does not equal MC_ℓ for the firms from which lumber cost data are obtained, ΔPS_1 will not equal ΔPS_2. P_ℓ will not equal MC_ℓ if the firms are not producing at their optimum levels, which is a common situation in the short run.

The estimate of ΔPS_1 will be less than the estimate of ΔPS_2, even if the relevant firms are producing at equilibrium levels, when average variable cost is increasing and is used as the estimate of $MC\ell$.

Changing Product Price

When changes in product output are large enough to affect product prices, the valuation problem becomes considerably more complex. Reduced product prices signify benefits to consumers and change in revenue to producers. Although only some of the producers in a given market may be directly affected by a change in the quantity or quality of some forest product, all producers in the market are affected by changes in end product price.

How well do the methods described above apply when forest or end product price changes as a result of a change in forest product output? The observation method cannot be used because we cannot observe the new price until it happens. The cost savings method circumvents the problem by definition—it only applies where the output quantity of the end product is constant, making the shape of the demand curve irrevelant. The change in net income method does not apply because the change in net income (the producers' surplus) for the firms affected by the change in output of a forest product would represent only part of the benefit, since consumers would also benefit, and because any firms in the market not directly affected by the change in output of the forest product would experience a decrease in net income because of lower end product prices.

An Approach Where the Forest Product Is Sold in a Competitive Market

Where the forest product is exchanged in a competitive market, and any products produced from the forest product are exchanged in competitive markets, valuation of the change is possible if both the prechange and postchange prices of the forest product are known. The prechange price is determined by observation of market data describing the existing situation. The postchange price depends on consumer tastes and preferences, availability and price of substitutes, prechange price, and change in quantity.

Economists use the concept of price elasticity to describe the price-quantity relationship, and thus the slope at specific points along the demand curve. Price elasticity is by definition the percentage change in quantity purchased (caused by a change in price) over the percentage change in price. For example, if an increase in the quantity supplied of some product resulted in a 5% increase in purchases and caused a 5% drop in price, the elasticity of that portion of the demand schedule is 1.0. If price dropped 10% with a 5% increase in quantity supplied, the elasticity of the relevant portion of the demand schedule is 0.5.

The postchange price can, therefore, be estimated if the analyst can estimate price elasticity for the expected change in quantity. While estimation of price elasticities is a complex topic beyond the scope of this paper, it should be mentioned that the analyst's first approach is to look for past studies which have developed demand schedules, or portions thereof, for the product and situation in question. This was the approach taken, for example, by Martin et al. (1978) in their estimate of the aggregate value of beef produced by the Arizona cattle industry. Using a small interval of a demand schedule of U.S. beef, they estimated that the average U.S. beef price would rise from $0.986 per pound to $0.997 if the Arizona beef industry suddenly disappeared.

With the constant product price situation it is sufficient to consider only the demand and supply schedules of the firms (e.g., timber mills, public forests) which are affected by the change in the forest product. Where the relevant price changes with the change in quantity of the forest product, one must consider the demand and supply schedules for the entire market, even though only some of the firms are affected by the change in the forest product.

For example, consider figure 8, where the hypothetical market is at equilibrium at point *a*, with 100 MBF of stumpage selling at $10 per MBF. Assume that the elasticity of demand has been estimated and that the demand curve is linear over the relevant output range. Assume further that S_1 is the current market supply curve and that one of the "firms" in the market, the Ponderosa Forest, is planning to increase production by 20 MBF per year at a cost to the forest of $6 per MBF (i.e., the Forest is experiencing constant costs, depicted by the horizontal segment *fg*), and that the costs of the Forest's inputs are competitively determined.

With the increase in output by the Ponderosa Forest, market equilibrium is at point b in figure 8. The change in producers' surplus is area *febg* − area $P_1aeP_2 \cong \$60 - \$95 = -\$35$. The change in consumers' surplus is $P_1abP_2 \cong \$105$. The net change in surplus is thus $fabg = \$105 - \$35 = \$70$. Note that, assuming S_1 and S_2 are parallel straight lines, area *fabg* is equivalent to area *habcj* (since *facg* is equivalent to *hacj*) and thus that the surplus is more easily calculated as $((\$10 + \$9)/2 - \$6)(20) = (\$3.5)(20) = \$70$.

The critical problem with this approach is that the new equilibrium (*b* in figure 8) must be known, which requires knowing not only the elasticity of demand for the relevant range, but also the slope of the supply curve over the relevant range. As Cory and Daubert (1981) state, such supply information is difficult to estimate and rarely available.

Two approximations of the true surplus are commonly used. The first simply assumes that price does not change (that the demand curve is horizontal as shown by P_1c in figure 8), yielding a surplus estimate given by area $facg = hacj = \$80$ in figure 8. Using this approximation is equivalent to applying the observation method. The other approximation, recommended for federal water resource planning (U.S. Water Re-

sources Council 1979, p. 30251), suggests that the elasticity of demand information be used, but that it be assumed that the full increase in output (20 MBF in figure 8) comes about. This method yields a surplus estimate of area *adjh* = \$60 in the example. In all cases of normal (upward sloping supply and downward sloping demand) curves, the first estimate overestimates, and the second underestimates, the real surplus. Cory and Daubert (1981) show that the maximum error in using either of these estimates is equal to the difference between them, which is $\frac{1}{2}(Q_3 - Q_1)(P_1 - P_3) = \frac{1}{2}(20)(\$2) = \$20$ in figure 8. The error may or may not be significant, depending on whether the decision to which the value estimate is an input will change if the estimate is varied by the estimate of the error. As Cory and Daubert demonstrate, in only some circumstances is the error inconsequential.

An Approach Where the Forest Product Is an Input

Figure 8 can also be used to depict the situation where the forest product being valued is not sold in a competitive market, but is used to produce another product which is. Assume, for example, that D and S_1 in figure 8 depict the demand and supply schedules for lumber, that an increase in output of stumpage from a forest allows some firms to increase production of lumber by 20 MBF, and that these firms experience constant variable costs of \$6 per MBF. Area *fabg* gives the correct measure of the gross surplus due to the increase in stumpage. The costs of the forest, necessary to bring about the increase, must be subtracted from this amount to give the net change in surplus.

Revenue and Cost Estimation

Application of the monetary valuation methods described in previous sections requires revenue and cost data. In this section, some sources of and problems with available data are discussed. Additional problems, introduced by inflation, are discussed in the following section.

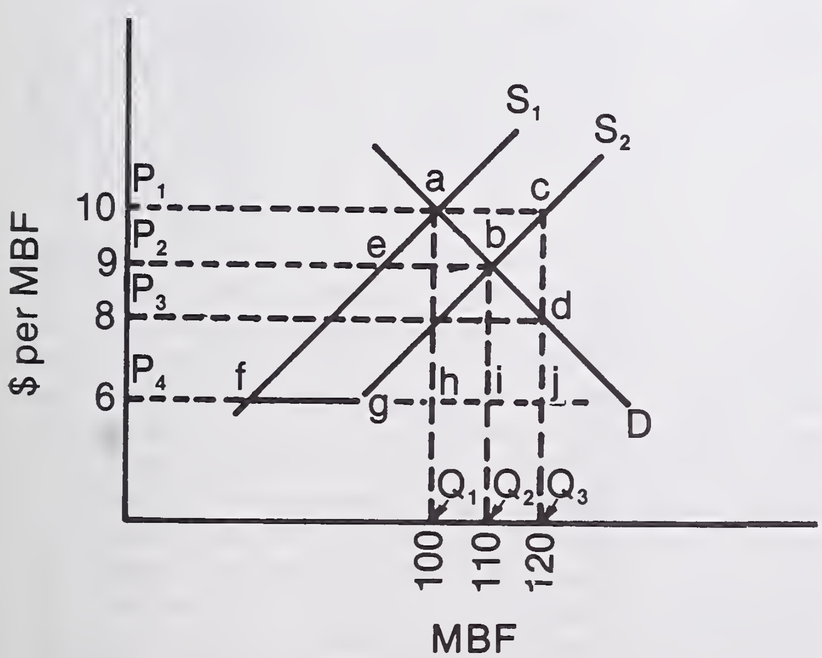

Figure 8.—Demand and supply schedules for a downward-sloping demand case. Adapted from Cory and Daubert (1981).

Revenue Estimation

Changes in revenue caused by changes in output of a forest product depend on the price of the end product for the respective situation and method being used. Data on market prices are often available, especially for commodities which are sold in relatively competitive markets. Application of the observation method to stumpage and the change in net income method to lumber is facilitated by such publications as the Commerce Department's quarterly *Forest Products Review*, and the Forest Service's biennial *Demand and Price Situation for Forest Products* or quarterly *Production, Prices, Employment, and Trade in Northwest Forest Industries*. Common sources of farm product and livestock prices, for use of the change in net income method, are agricultural and statistical reporting services, generally connected with agricultural experiment stations. Eisenman et al. (1980) provide a guide to sources of data concerning timber, range, and water in the western United States. If price is expected to change as a result of the change in the forest product, price elasticity information may be needed in addition to data on actual prices.

Cost Estimation

To calculate how total cost will change with an increase in output, one must know for the affected firms or forests just what costs will change and how they will change. Total cost can be separated into fixed and variable costs. Fixed costs are those which do not vary as output varies in the short run, such as insurance, interest, and management salaries. Variable costs do vary as output varies in the short run; examples are wages and materials. Marginal cost is the change in total cost of a unit change in output. Because total variable cost, but not total fixed cost, varies in the short run with changes in output quantity, marginal cost changes as variable cost changes. If average variable cost decreases with a change in output, marginal cost is less than average variable cost, and if average variable cost increases, marginal cost is greater than average variable cost. If average variable cost is constant over some range of output, marginal cost is equal to average variable cost.

The change in total cost with a small change in output is approximated by the marginal cost times the output change. Unfortunately, marginal cost data are rarely available, forcing the analyst to rely on average cost data. As described above, where average variable cost is constant (the average cost curve is horizontal) over the relevant range of output, average variable cost equals marginal cost and, thus, can be used to estimate accurately the change in total cost. Several

empirical studies of cost curves of individual firms have been made in recent years. "Most of them suggest that short run marginal cost curves are horizontal over the usual range of output . . ." (Friedman 1976, p. 143).

For many cases of lumber, livestock, and crop production, it seems reasonable to assume that average variable cost is constant over relatively small changes in production. The implicit conditions of constant average variable cost with a change in output are constant prices of all variable inputs and constant returns to scale. The first condition is quite reasonable where changes in output are small relative to the total market quantity supplied. The second condition depends on the fixed plant of the individual firms. Some firms have a mix of fixed cost inputs, such as fences, water developments, corrals, horses, etc. for a ranching firm, which allow considerable change in output without changes in average variable costs. Others do not. The case where the average variable cost of producing an increase in output is the same as that for the original output quantity is depicted in the move from 5 to 6 MMBF in figure 5. The total change in cost in this case is equal to average variable cost at 5 MMBF times the change in output.

If average variable cost is expected to increase for the relevant change in output, one must estimate the change in order to calculate the change in total cost. As stated above, this is difficult because of the lack of marginal cost data. Analysts often ignore a possible increase in average variable cost for an output change if the increase is considered minor. Where average variable cost is increasing for the specified change in output, prechange average variable cost will underestimate marginal cost, and the estimated change in net income (and thus the benefit), will be overestimated. For example, consider the increase in output from 6 to 7 MMBF in figure 5. The rising marginal cost curve over this range implies that average variable cost is also increasing (i.e., if total cost increases by continuously increasing amounts with each additional unit of output, average variable cost must also be increasing). The actual change in total cost for the 1 MMBF increase is about $450,000. Applying prechange average variable cost to the change results in an estimate of $400,000 for the change in total cost.

For public agencies, a common problem in cost estimation is that cost data for individual firms are rarely available. Rather, the available data represent an average of several firms or are in terms of "representative" firms. Often two to four firms are chosen to represent a range of firm sizes. For example cost data might be estimated for three representative ranches, of 100 animal units, 250 animal units, and 600 animal units. The cost data for each representative firm could have been based on the costs for specific firms, but more generally are based on data from several firms of the approximate size of the representative firm. Thus, the analyst generally must estimate the costs of the firms affected by the change in forest product output from cost data which only approximate the costs of the affected firms.

The distinction between fixed and variable costs is sometimes misleading. It is possible that costs normally considered fixed will change with a specified change in forest product output. For example, in order for a rancher to properly utilize an increase in available livestock forage, additional fences and water development may be necessary. Such developments are considered part of the fixed ranch investment because they are durable and not divisible to the animal unit level. However, as herd size increases, points will be reached when additional fixed cost inputs are necessary. If some fixed cost items change as a result of the change in forest product output, those fixed costs become variable from the standpoint of the derivation of the value of the change in forest product.

Even if obvious changes in fixed costs are accounted for in a valuation effort, the resultant monetary value must still be considered a short-run value. In the long run there may be other changes in the cost structure of the firm or forest, perhaps as a result of new technology. Such changes can rarely be predicted and may have little or no relationship to the forest product change being valued. Nevertheless, they may alter, expost, the value of the change in forest product output. If the expost change in the monetary value occurs within the planning horizon in which the monetary value is being used, an error is introduced.

Two problems in calculating net change in surplus arise because of the long production periods for some forest products and because of the multiproduct nature of most public forests. To examine these problems, consider a forest producing timber and providing wildlife habitat and recreation opportunities. Some of the forest management costs, such as the cost of sale administration, occur at the time of harvest and are totally assignable to the harvest. Others, such as the cost of pruning, while perhaps totally assignable to timber production, precede commercial harvests, and may only occur once or twice per rotation. The costs which are not incurred at the time of harvest but which are directly attributable to the resultant stumpage must be allocated to the harvests they support and expressed in comparable dollars to those of the harvest to which they are allocated. While this can be done, it usually requires somewhat arbitrary decisions about the proper allocation and about the proper discount rate.

The other, and more serious, problem is that other costs may not be attributable to only one product. For example, precommercial thinning may affect some wildlife species, and roads built to facilitate harvest may affect access for recreationists. There is no correct way to allocate such costs among the various forest products. The only theoretically neat way around the dilemma is to compare the multiple benefits and costs of entire land management alternatives. In such a comparison, all relevant costs and benefits are included, but ambiguous cost allocation efforts are avoided. As long as all costs are included in the overall analysis, estimates of gross change in surplus are adequate measures of value.

Price Changes Over Time

The procedures described above for valuing changes in forest product output rely on estimates of market prices which apply to a specific time period. Commonly this period is a calendar year which has been chosen as the base year for the planning exercise. Prices generally change considerably over time, which causes problems when analysts (1) use data from past years to estimate prices for the base year and (2) apply the base year estimate to future years.

Base Year Estimates

Generally the analyst needs to calculate a shadow price which represents what the base year price would be in the absence of short-term abnormalities caused by weather, foreign demand, and other fluctuating influences. It is generally safer to base this shadow price estimate on price data for several past years, rather than on just the most recent year, in the hope that short-term abnormalities will cancel out.

The simplest and least satisfying approach is to average the prices for several recent years. The most serious problem with this approach is that it ignores the influence of inflation (deflation), thereby underestimating (overestimating) the price. This problem can be largely corrected by updating each year's average price to the base year using factors which express the change in an appropriate price index, such as the wholesale commodity price index. That is, the factor for each year, to be multiplied times the actual year's price, is the base year price index divided by the price index for the respective year. Such indexes can be found in numerous publications, such as the Survey of Current Business published by the Census Bureau.

A more common procedure for estimating base year price is to calculate a linear or nonlinear trend line from data for recent years using simple linear regression. This method averages out short-term fluctuations, and also accounts for the general upward trend of inflation. This method too, however, has problems. As Niehaus (1978) observed, it is adequate during periods of relatively stable prices, but is of limited value when prices fluctuate widely.

The weighted average approach, which combines elements of the inflation-adjusted average and the trend line, is sometimes used when the base year is also the current year. With this approach, the inflation-adjusted prices for each year are multiplied by the associated volume produced, for the market in question, to give total value by year. Regression is then used to predict the current year total value. Regression is also used to predict the current year total volume produced. Then the predicted total value is divided by the predicted volume to yield the predicted unit value. The rationale behind this approach is that unit value is in fact a function of volume produced, and that basing the value on predicted volume is more accurate than ignoring volume.

Niehaus (1978) describes more sophisticated approaches, such as the zero-one shift method and structural approaches. These approaches require a thorough knowledge of the markets for the products being priced, and are not of practical use to the analyst unfamiliar with such markets. However, the analyst may be able to rely on the expertise of others. The U.S. Water Resources Council, for example, publishes agricultural prices calculated using a weighted average technique (see, for example, U.S. Water Resources Council 1978).

Future Prices

In many analyses of alternatives for future land management, the base year price estimates are applied to future years, completely ignoring any possible inflation (or deflation) of those prices. This decision is based on the assumption that inflation will affect all relevant costs and benefits similarly, making inflation of no consequence for comparing alternatives. If the inflation of the relevant costs and benefits is that of the average of all goods and services, the "real" prices of those costs and benefits are said to be constant. However, if the price of a cost or benefit does not change as do the average prices of all goods and services, then its real price is said to change, and this real price change should be accounted for in the analysis.

Changes in real prices occur with changes in any of the determinants of the demand and supply schedules. For example, the real price of timber might rise if consumer tastes change favoring wood products over substitutes such as plastic and metal. Or the increasing scarcity of petroleum may raise the cost of petroleum products, causing greater demand for wood products as fuel and thereby raising real prices of wood products. On the other hand, improvements in harvesting and milling technology, which allow reductions in lumber production costs, may cause corresponding decreases in lumber prices.

Where there is strong reason to believe that the real price of some cost or benefit will change over the planning horizon, the analyst may want to include this change. Estimates of future real price changes are usually based on past real price changes and an understanding of the demand and supply situations for the product in question (and, therefore, for its substitutes). There is strong evidence, for example, that the real price of wood products will rise. The real price for wood products nationwide has risen an average of about 1.4% per year over the past 100 years, with real lumber prices increasing an average of 2.2% per year over the same period (Manthy 1978).

The choice of a specific real price rise to apply to future years is guesswork, however. Numerous problems arise. For example, sawtimber prices have risen faster than the average, but pulpwood prices have risen slower—would the products from the planning area be of the same composition as the national average? Real sawtimber price rises during the past

10 years have been much higher than the long-term average rise—is this short-term trend a more realistic example of the future than the long-term trend? Will the increasing price of wood products make substitutes, heretofore not used because of prices, more viable alternatives to wood, thereby reducing increases in the demand for wood products? Clearly, any estimates of future real price changes are risky, requiring that the results of a comparison of alternatives be subjected to sensitivity analysis to make visible the importance of real price change assumptions.

Another cause of changes in resource values is changes in the capital structure of firms which use the resources as inputs in the production of end products. Consider a group of farms which would use additional runoff to produce additional outputs of alfalfa and barley. The change in net income to these farms would be different if they changed the irrigation systems to more efficiently use water and power. The water value derived using the change in net income method based on the original capital structure would be different if the new structure were in place. Such changes are difficult to anticipate and measure.

PART II: EXAMPLES OF MONETARY VALUATION OF TIMBER, FORAGE, AND WATER IN CENTRAL ARIZONA

The constant product price methods described in Part I are demonstrated here using numerous examples of changes in stumpage, livestock forage, and water runoff outputs from central Arizona forests. Realistic land management planning decisions regarding these forest products in central Arizona are not likely to require use of changing product price methods. The reader might wish to consult Cory and Daubert (1981) for an example of the use of such methods.

In all cases, gross monetary values are estimated. Such values do not account for the administrative and other management costs to the forest of providing the changes in forest output. These forest costs would have to be subtracted from the gross values in order to obtain net values.

Numerous externalities, some positive and others negative, are associated with forest activities to change outputs of stumpage, forage, and water. For example, changes in timber harvest, livestock grazing, and water runoff may all affect onsite wildlife habitat, scenic quality, and soil fertility. Possible offsite externalities include changes in air pollution from milling of lumber and changes in recreational use of streams and lakes or reservoirs. Such externalities are real costs or benefits which should be accounted for in the overall planning effort for which the monetary values derived using the methods described herein are estimated. It is not the purpose of this paper, however, to deal with such costs and benefits.

TIMBER STUMPAGE

Market Characteristics

Arizona timber is sold as sawtimber, pulpwood, Christmas trees, and firewood. Christmas trees and firewood account for very little of the total standing timber sold and will not be considered here. Sawtimber (the trees of 11 inches or greater in diameter at breast height) has accounted for over 85% of the total volume of sawtimber and pulpwood stumpage cut in recent years. The sawtimber is mainly used by Arizona mills to produce lumber, but a small amount of poles and molding are also produced. The pulpwood, as well as much of the chips left over from lumber production, are used by the pulpmill to produce kraft liner board and newsprint.

The stumpage market in Arizona fails to meet three of the four conditions of competition. First, there is not a large number of buyers and sellers. Only 4% of the commercial forest land in Arizona is privately owned. Sixty-nine percent is on national forests, 26% is on Indian reservations, 1% is on state land, and 0.2% is managed by the Bureau of Land Management. Furthermore, the number of buyers is small and has gradually declined. In 1946 there were 66 sawmills producing lumber in Arizona, in 1965 there were 25 and in 1974 there were only 16. Nine of 16 sawmills were owned by four firms, and these four purchased nearly all the timber from national forest land.

The small number of buyers is reflected in bidding behavior for national forest timber. For 1960-1974, timber sale records for Arizona national forests show that only 24% of the sales had more than one bidder and that only 13% sold at greater than one percent above the appraisal value. For pulpwood, the buyers market is monopolized, because there is only one pulpmill close enough to the raw material to purchase it economically.

Second, there is a lack of free entry. Entry into the sellers market is limited by public ownerships of nearly all the commercial timber. Entry into the buyers side is limited on national forests by institutional arrangements and on Indian reservations because most timber is harvested by tribal enterprises. The Colorado Plateau Pulpwood Agreement of 1957, between the USDA Forest Service and Southwest Forest Industries, assures the firm a 30-year supply of pulpwood at an administered price and effectively eliminates other buyers. Until it was tentatively abolished in 1980, the Flagstaff Federal Sustained Yield Unit, established in 1949 under the Federal Sustained Yield Act of 1944, required that 85% of the allowable cut from the Unit be given primary manufacturing within the city of Flagstaff or three miles thereof and that the remaining 15% be offered for sale to other purchasers without regard to location of manufacture.

The third competitive market condition is product homogeneity. The market fails this test because each sale is unique: volume, timber species, wood quality, accessibility, and other characteristics differ from one sale to the next.

The fourth condition, perfect knowledge, is fairly well met. Market information appears to be adequate. National forest timber sales are advertised, and information, such as the volume of timber sale, its appraised price, the location of the sale, and the physical characteristics of the timber, is readily available. Thus, all potential buyers of public timber within the specified region are given equal market information about the appraised price and timber characteristics.

While the Arizona stumpage market exhibits little competition, the markets for wood products are generally very competitive. According to Mead (1966) "The United States timber industry is frequently cited by economists to illustrate a real world approximation to the model of pure competition...we find that individual firms, even the largest, face a perfectly elastic [horizontal] demand curve for their lumber, and that the profit rate is no higher than that hypothesized by the competitive model." Although the stumpage market is often a local market, lumber products are sold nationwide. For example, lumber producing firms in Arizona sell ponderosa pine lumber throughout the country at competitive market prices, and Arizona businesses which use lumber as an input buy lumber from other parts of the country as well as from local mills. Because there are thousands of sellers and buyers of lumber products interacting with each other in the market, no single buyer or seller can change the lumber product price.

There are no institutional barriers to exit and entry into the lumber industry. There is a free flow of information on price and product quality throughout the country. Several wood product associations and timber purchaser associations attempt to enforce uniform lumber standards and grading rules around the country, enhancing product homogeneity.

The basic wood products, such as pulp and lumber, are, in turn, used to produce a number of products, including paper, furniture, pallets, and buildings. The markets in which such products are exchanged are all rather competitive.

Valuation

Two examples of valuation are presented here. The first is of a change in sawtimber quantity, and the second a change in pulpwood quantity.

A Change in Sawtimber Quantity

Let us assume that a national forest in Arizona is considering several alternatives for future management of the forest, and specifically that alternative B will increase the quantity of timber available for harvest over that with alternative A, which is a continuation of current management direction (the "without" alternative). Further, assume that the average quality of the timber is unaffected by the quantity change (step 1, p. 5) and that the increase is located in numerous prospective sale areas throughout the forest and would most likely be harvested as an additional 100 MBF per year and used to produce lumber (step 2). The forest planning team needs an estimate of the value to society of the additional 100 MBF per year from the efficiency standpoint (step 3).

The question is (step 4), "What valuation method should be used?" The observation method is a poor choice in this situation. Although competitive markets for ponderosa pine stumpage do exist, and average stumpage prices from such markets are published, it is very difficult to decide which market best represents the resource in question. For example, in the third quarter of 1977 average ponderosa pine stumpage prices for national forests in the Northwest averaged $147 per MBF and ranged from $59 to $223 per MBF (Ruderman 1978).

Because of the market characteristics, derivation of the sawtimber stumpage value from the value of lumber is the most promising approach. The change in net income method applies: The end product and all subsequent products are exchanged in relatively competitive markets, the increase is too small to change the price of the end product, and the producers' variable inputs, other than stumpage, are exchanged in at least relatively competitive markets. The most appropriate model for application of the change in net income method is figure 5.

Each month the Western Wood Products Association publishes a price trend index for ponderosa pine based on lumber transactions throughout the West. While this is useful in updating regional prices, the west-wide prices themselves do not apply to specific regions or forests. The most localized lumber price data for Arizona are those published by the Forest Service's Southwestern Region, which encompasses Arizona and New Mexico. Each year the Southwestern Region publishes selling price per MBF for four different species, weighted by grade volumes. Thus the average price is that for the log of average grade.

In order to estimate a ponderosa pine lumber price for 1977, we might calculate a trend level price based on average prices for the 10 most recent years, as listed here in lumber tally (LT) terms:

Year	$/MBF LT
1967	78.20
1968	95.95
1969	116.99
1970	97.74
1971	117.63
1972	140.78
1973	180.90
1974	167.58
1975	149.62
1976	197.54

A straight line least squares fit yields a 1977 price estimate of $200 per MBF LT ($r^2$ = .84). However, there is some evidence to suggest that price changes in the 1960's are a poor basis for prediction in the forseeable

future. Straight line least squares fit on data for 1970-76 gives a 1977 price estimate of $206 per MBF LT ($r^2$ = .74). And, because a plot of the actual prices showed some nonlinear tendencies, the data were fit to an equation of the form price = $a(\text{time})^b$. This yielded an estimate for 1977 of $195 per MBF LT ($r^2$ = .84). A corresponding inflation-adjusted price estimate, based on 1970-76 data, gives a 1977 price estimate of $210 per MBF LT. And the weighted average approach, using a straight line fit to predict the 1977 total value and volume, gives a 1977 price estimate of $215 per MBF LT. Based on these estimates, it seems reasonable to assume that the price will, in the absence of short term fluctuations, be between $195 and $215 per MBF LT. (The actual average 1977 price was $233 per MBF.)

The following types of costs are involved in the cost estimates. Variable costs include all expenses which vary in the short run depending on the quantity of production, where the short run is a logging season for logging operations or fiscal year for a mill. In the logging operation variable costs include such items as felling, bucking, skidding, loading, and hauling. They also can include expenses necessary to deal with damage which the harvest causes to the site or the transportation system, provided such expenses vary as harvesting level varies (e.g., road maintenance and slash disposal). In the mill, the variable costs include labor, materials, power, and other costs which vary as output varies for all operations in the log yard, from yard, to sawmill, to greenchain, to shipping.

Fixed costs include all expenses which do not vary as output varies in the short run (e.g., administrative salaries, property taxes, depreciation, and insurance). Fixed costs also include road construction, sale administration, and other costs which may not vary significantly with sale volume.

In the short run, total variable cost will increase for firms which harvest and mill the additional stumpage. Even if it were certain which firms would harvest and mill the additional stumpage, cost data for the individual firms would most likely be unavailable. The only readily available cost data for Arizona lumber firms are published by the Forest Service's Southwestern Region. These data are compiled in two parts. The harvesting costs are simple averages of harvesting firms which contribute their cost data, with most firms in the region contributing. The milling (manufacturing) costs are the averages of the firms contributing, weighted by mill production. Although the Forest Service collects cost data from individual firms in order to calculate these regional averages for the purpose of timber sale appraisal, the individual firm data is proprietary and supplied to the Forest Service with the understanding that only averages will be published and used.

Ideally, the marginal cost would be known for each individual harvester and mill which would be affected by the change in harvest. Because only average cost data, averaged over most operators and mills in the region, are available, it is important to determine whether or not the average variable cost data available actually approximates the relevant marginal costs? This question can be approached in two parts: First, "Will the average variable cost of each affected operator and mill approximate its marginal cost?" Second, "What problems are introduced by averaging over most operators and mills?"

Economic theory of the firm is of some help in answering the first part. First, consider the harvesting operation. Typically, variable costs account for 80% or more of total costs. Furthermore, vehicles and machinery, the major components of fixed cost, are relatively easily and quickly bought and sold, and thus may be treated as variable costs for all but the very short run. Therefore, only the inability of management to efficiently handle increased output would cause average variable cost to increase significantly as output increases. This is not likely to be the case, leading one to the conclusion that average variable cost is relatively stable with small changes in output, and that marginal cost is not significantly different from average variable cost (figure 9).

With milling operations, variable costs account for about 75% of total cost. In Arizona, all mills are typically producing at levels well below their stated capacity, evidenced by the fact that most mills work only one shift and none work more than two. This is because of the limited quantity of timber supplied from the national forests. This fact suggests that they are producing at levels where average variable costs are not changing much with changes in output—the capacity of the plants is not close to being taxed. Thus it seems reasonable to assume that the average variable cost curve is either constant or dropping or rising at a low rate, meaning that marginal cost approximates average variable cost. This is depicted by the shift from Q_1 to Q_2 in figure 9.

Now for the second part of the question, "What problems are introduced by using regional average costs?" If the analysis is regional in scale, involving timber harvested from all areas of the region, the error introduced by using regional average costs is probably relatively insignificant. However, if the analysis is of a very localized situation, where a limited number of firms are involved, the real costs of such firms may be quite different from the regional average. In this case, the error in valuation may be significant. Localized adjustments in some costs may be feasible, such as in costs for harvesting, hauling, and slash disposal, but

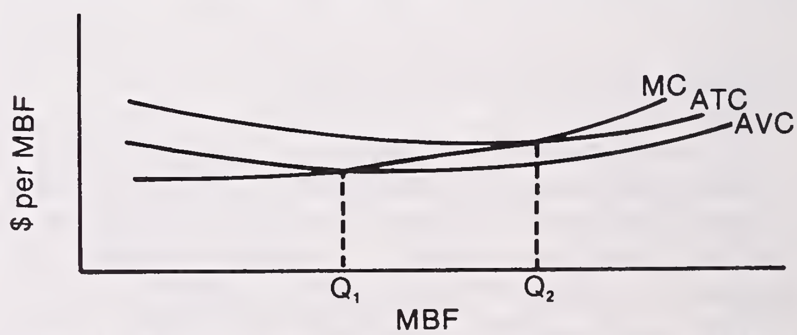

Figure 9.—Expected cost situation for harvesting firms—because average variable cost (AVC) changes very little within a reasonable range of production (Q_1 to Q_2), AVC at any one time approximates marginal cost (MC).

adjustments in milling costs are much more difficult to make. Here again a range may be more appropriate than just one best guess figure.

Proceeding with the example on the basis that regional average costs are appropriate, the following variable costs per MBF log scale (LS) for 1977 were calculated from a linear trend of costs for 1970-76:

Fall and buck	$ 8.70
Skid	9.98
Load	4.48
Haul	12.80
Road maintenance	1.90
Slash disposal	10.01
Erosion control	.63
Manufacturing	69.19
Miscellaneous	2.21
Total	$119.90

The corresponding fixed costs total $46.72, resulting in average total cost of $166.62 (the actual regional average cost in 1977 was $167.19).

Converting the lumber tally selling prices of $195 and $215 per MBF to log scale, based on an overrun estimate of 1.25, yields end product selling prices of $244 and $269 per MBF. Subtracting out average variable costs yields a range of change in net income per MBF of $124 to $149. Thus, the gross value to society of the increase in harvest is from $130 to $149 per MBF. In the absence of simulations or other information about future prices, one may assume past trends will continue into the future. Based on past trends, the value can be expected to increase in real terms at a rate of 2.2% per year (Manthy 1978).

A Change in Pulpwood Quantity

Let us assume that an alternative timber management plan would increase the quantity of pulpwood available for harvest on an Arizona forest (step 1). The only use of harvestable pulpwood in Arizona is by the pulpmill in Snowflake, Ariz., in making liner board and newsprint. However, would this use really be affected by the increase in available pulpwood; that is, would the increase be harvested and milled (step 2)?

Historically not all the available pulpwood has been purchased. Thus, an increase may remain on the stump or merely substitute for other pulpwood which would have been harvested if the new supply did not become available. If it remains on the stump, it has no current value as pulpwood. If it substitutes for less accessible pulpwood, and is used to produce pulp products (step 3), it can be valued using a cost savings approach (step 4). The value is the harvesting savings, of from zero to about $7.00 per cord and the hauling savings, of about $0.13 per mile per cord. This is not a savings on all production, as depicted in figure 4. Rather it is a savings over a relatively small portion of the total production.

However, if future liner board and newsprint prices were to make greater pulpwood harvests attractive, the increases in available pulpwood could augment in value. If such were the case, the change in net income method would be the most appropriate valuation method. However, the unavailability of milling cost estimates for the mill in question precludes use of the change in net income method.

FORAGE FOR LIVESTOCK

Market Characteristics

The forage market is not very competitive, largely because of the small number of sellers and the lack of free entry. Nearly 82% of the land in Arizona is publically owned, and over 82% of the grazing in the state is on public land. For almost all of the public land, there is no forage market. Rather, the permittees are charged an administratively set fee per animal unit month (AUM) of grazing. While there have been some efforts on the part of some of the land management agencies to charge the "fair market value" for the forage, there is general skepticism that the administratively set fees approximate a shadow price for forage.

The buyers of forage on public land are the permittees who hold grazing permits. Such permits are generally held for long periods and are usually tied to private land holdings in the proximity of the permit area. As long as the permittees continue to properly use the forage, their right to the forage is not questioned.

A forage market exists for privately held forage. However, while there are no restrictions to entry of the private forage market, the logical buyers of grazing rights are owners of adjacent or nearby rangeland, limiting the number of practical buyers for any particular grazing right.

The livestock market, on the other hand, is very competitive, not only in Arizona, but throughout the United States. Ranchers in Arizona compete with each other and with ranchers from neighboring states in selling their livestock. Cattle feed lots are numerous. Livestock are sold both by auction and directly from the ranches. There are large numbers of buyers and sellers, entry and exit to the market is not restricted except for public land on the sellers side, product information is ample, and the products are rather homogeneous.

The principal product made from livestock is meat. As with most foods, the market for meat is highly competitive.

Valuation

The most common valuation example will be considered here—that of an increase in forage quantity (step 1). The site used here is national forest land in the Salt-Verde Basin, an 8.4 million acre area in central Arizona. National forests cover 64% of the Basin, and nearly all the national forest land in the Basin is grazed. A change in forage quantity will principally af-

fect cattle, deer, and elk (step 2). Let us assume that forest planners want to know the unit value in terms of livestock grazing of a marginal increase in forage on national forests in the Basin (step 3)?

Two methods could be used to approach this problem, the observation method and the change in net income method (step 4). The data supporting the observation method are the average annual private lease rate of an AUM, published for selected states by the USDA in an annual publication titled "Farm real estate market developments."

The rate for Arizona for the ten years prior to 1977 was as follows:

1967	$2.84
1968	3.16
1969	2.91
1970	3.44
1971	2.78
1972	2.52
1973	2.79
1974	3.21
1975	4.60
1976	4.15 (estimate)

Unfortunately, 1975 was the last year for which a separate Arizona rate was published. Data for 1967-76 yields a 1977 value of $3.94 per AUM with a poor linear fit to the data (r^2 = .35). Data for 1971-76 yields a value of $4.69 per AUM with a much better fit (r^2 = .74). The value for the average grazing land on private land in Arizona probably lies between about $4.00 and $4.70 per AUM.

It is safe to say that the average public grazing land in Arizona is of lower quality than the average private grazing land, because much of the public grazing land is in timbered areas or on steeper slopes than is most private grazing land. This suggests that the gross value for the national forest land in the Salt-Verde Basin is lower than the $4.00-$4.70 per AUM estimate.

Use of the change in net income method requires much more effort than use of the observation method. Ranchers' income will change with an increase in forage for livestock grazing if the additional forage allows an increase in grazing. If so, the change in net income for an affected ranch equals the market value of the additional animals produced minus the change in total cost associated with the additional animals. As long as the prices of the ranchers' variable inputs are determined competitively, the change in net income is an appropriate measure of the gross change in producers' surplus.

Mathematical optimization models, such as linear programming, are sometimes used to model rancher operations with changing forage availability. This approach has the potential of more accurately estimating the change in net income than the simpler approach demonstrated here.

Because the livestock market is competitive, and because the change in total market production associated with a small increase in forage in the Salt-Verde Basin is not expected to be large enough to affect livestock prices, the market prices for the base situation are appropriate to use in calculating the unit value to society of the increase. The Arizona Crop and Livestock Reporting Service (1978) reported the following average sale price per pound for range fed cattle for the ten years prior to 1977:

	Calves	Yearling steers and heifers	Cows
1967	$0.252	$0.242	$0.157
1968	.265	.254	.168
1969	.299	.288	.193
1970	.329	.288	.198
1971	.359	.311	.209
1972	.432	.348	.239
1973	.536	.438	.297
1974	.363	.406	.237
1975	.284	.401	.205
1976	.341	.378	.254

Based on these data, the trend line (least squares linear regression) prices for 1977 are $0.410 for calves, $0.446 for yearlings, and $0.272 for cows (the actual 1977 prices were $0.375, $0.391, and $0.243, respectively). Conklin and Young (1977) suggest a method which yields similar results.

The marginal cost of the affected ranches is the most appropriate cost to use to calculate the change in total cost, but marginal cost data are not available. The common assumption in this case is that average variable cost approximates marginal cost, which is equivalent to assuming constant marginal cost (similar to the shift from 5 to 6 MMBF in figure 5). This assumption is generally considered safe for ranching enterprises, but certain adjustments from the common categorization of variable costs for ranching operations are necessary to calculate the marginal cost for public land planning.

First, the variable costs of ranches using public grazing land typically include livestock taxes and grazing fees. Although these items are out-of-pocket costs for the ranchers, they are merely transfer payments from the point of view of society, and are excluded from calculation of the change in net income when deriving the marginal value of forage to society. Second, bulls are typically considered a fixed cost of ranching operations. However, the number of bulls maintained usually varies with the size of the cow herd. If this, or any other "fixed" cost (fences, water developments, horses, etc.) changes with the predicted change in production, the change becomes a variable cost for the calculation of the change in net income. Finally, the interest on the investment in the breeding stock is often listed with fixed costs. However, as the size of the breeding stock changes to allow the change in produc-

tion, associated interest changes also change, and this change must be accounted for in calculating the change in net income.

Central Arizona ranch budgets are available from two recent studies. Martin and Snider (1980) calculated 1977 budgets for four representative yearling ranching operations representing ranching throughout the national forests in the Salt-Verde Basin. Menzie and Archer (1975) calculated a 1974 budget for a representative cow-calf operation. The results from each of these studies are used here to estimate the change in net income.

As an example of the yearling budgets, consider table 1, which lists the variable costs for the 299 animal unit ranch. A $12,000 charge for the owner's labor is included. For deriving the marginal value of forage from society's viewpoint the average variable cost per AUM is $11.54 (($48,251 − $1,159 − $5,699)/(299 × 12)).[5]

The annual returns from the 299 AUM ranch are estimated as follows:

Cull cows	19 × 850 lbs × $0.27/lb. =	$ 4,361
Yearling heifers	49 × 580 lbs × $0.45/lb. =	12,789
Yearling steers	74 × 620 lbs × $0.45/lb. =	20,646
		$37,796

[5]*This analysis is based on the assumption that a 299 animal unit ranch actually consumes 299 animal units of forage; that is, that the method of accounting for animal units accurately reflects the forage consumed. Martin and Snider (1980) assume otherwise.*

This return, equivalent to $10.53 per AUM, minus the average variable cost of $11.54 per AUM, yields a best guess gross value per additional AUM of forage of −$1.01. The values for the four representative ranches are summarized in table 2 for highs, lows, and best guesses of cattle selling prices.

If the alternatives being analyzed were such that specific ranches could be isolated, then each affected ranch could be compared to one of Martin and Snider's four representative ranches. If one wanted an average value for ranches on national forests in the Salt-Verde Basin, a weighted average value could be calculated using the proportion of the total AUM's associated with each representative ranch. From table 3, the four ranches represent 18%, 22%, 27%, and 33%, respectively, of the total grazing on national forest land in the Basin. With these weights, the best guess of the average gross value of forage in the Basin is −$0.85 per AUM.

The representative cow-calf ranch is a 368 animal unit operation. Annual returns in 1977 dollars are as follows:

Cull cows	30 × 850 lbs. × $0.27/lb. =	$ 6,885
Steer calves	80 × 385 lbs. × $0.41/lb. =	12,628
Heifer calves	120 × 430 lbs. × $0.41/lb. =	21,156
		$40,669

This is equivalent to $9.21 per AUM. Total variable cost, updating from Menzie and Archer (1975) using an inflation factor of 1.21 as calculated from the whole-

Table 1.—Variable costs for a 299 animal unit central mountain cattle ranch, 1977[1]

Item	Explanation	Cost	($)
Feed			$ 4,422
Alfalfa hay	9 tons @ $65/ton	$585	
Grain	2 tons @ $135/ton	270	
Mineralized salt blocks	48 cwt. @ $4.00/cwt.	192	
Range cubes (supplements)	450 cwt. @ $7.50/cwt.	3,375	
Labor			13,200
Owner	Full time @ $1,000/month	12,000	
Seasonal	2 man-months @ $600/month	1,200	
Vehicle (gas, oil, repairs)			5,835
Utilities $135 per month			1,620
Livestock taxes[2]			1,159
Bulls		146	
Cows		625	
Yearlings		387	
Grazing fees			5,669
Veterinary			330
Repairs on capital investments			1,710
Insurance			943
Miscellaneous expense			110
Brand inspection		35	
Bookkeeping, dues, subscriptions, etc.		75	
Interest on borrowed operating capital[3] 10% × ½ (22,998)			$1,150
Normal variable costs			36,148
Variable "fixed" cost—bulls			1,087
Opportunity cost—interest on bulls, cows, and yearlings			11,016
Total variable costs			$48,251

[1]*Adapted from Martin and Snider 1980.*
[2]*$9 per $100 assessed valuation: Assessed at 18%*
[3]*$22,998 excludes owner labor.*

Table 2.—Marginal value of forage for four representative ranches, Salt-Verde Basin of Arizona, 1977

	151[1] AU's			299[2] AU's			468[3] AU's			701[4] AU's		
	High[5]	Best guess[6]	Low[7]	High	Best guess	Low	High	Best guess	Low	High	Best guess	Low
Gross return per AUM[8]	14.09	10.56	7.96	14.05	10.53	7.94	14.09	10.57	7.97	14.13	10.60	7.99
Variable cost per AUM[9]	15.49	15.49	15.49	11.54	11.54	11.54	11.16	11.16	11.16	9.34	9.34	9.34
Net per AUM	−1.40	4.93	−7.54	2.51	−1.01	−3.60	2.93	−0.59	−3.19	4.79	1.26	−1.35

[1]*Cattle sales of 10 cows, 25 yearling heifers, and 37 yearling steers.*
[2]*Cattle sales of 19 cows, 49 yearling heifers, and 74 yearling steers.*
[3]*Cattle sales of 30 cows, 77 yearling heifers, and 116 yearling steers.*
[4]*Cattle sales of 45 cows, 115 yearling heifers, and 175 yearling steers.*
[5]*Highs are based on selling prices of $0.60 per pound for yearlings and $0.36 per pound for cows.*
[6]*Best guesses are based on selling prices of $0.45 per pound for yearlings and $0.27 per pound for cows.*
[7]*Lows are based on selling prices of $0.34 per pound for yearlings and $0.20 per pound for cows.*
[8]*Cattle weights of 850 lb., 580 lb., and 620 lb. for cows, yearling heifers, and yearling steers, respectively.*
[9]*From Martin and Snider (1980), excluding livestock taxes and grazing fees and including allowances for owner labor, and depreciation and interest on breeding stock.*

sale commodity price index, and including $12,000 for operator labor, equals $47,478, which is equivalent to $10.75 per AUM. This results in a gross value of additional forage of −$1.54 per AUM.

A recent study[6] of ranching in Colorado offers an opportunity to check the costs and returns upon which these values are based. The 1977 Arizona ranching cost estimates are generally lower than those for similar sized ranches in Colorado, while the returns are comparable. Thus, we have no evidence that the Arizona costs were overestimated or the values underestimated.

The best guess of the gross marginal value to society of forage for livestock on national forests in the Salt-Verde Basin varies from no value for the smaller ranches to $1.26 per AUM (1977 dollars) for large ranches (table 2), with no value on the average. The highs range from no value for the smaller ranches to $4.79 per AUM for the large ranches, with a weighted average value of $2.67 per AUM.

The values are very sensitive to livestock price fluctuations (for example, see Martin and Snider 1980). Although applying the trend lines calculated from 1967-76 prices to 1977 overestimated actual prices, the trend lines underestimated actual prices for 1978 through 1980 by from 10 (yearlings in 1978) to 50% (calves in 1979). If a strong case can be made that the actual 1977 price was unusually low and did not represent future conditions, then perhaps the high estimate is more accurate than the best guess. In any case, sensitivity analysis should be used to determine how sensitive the results of a comparison of alternatives is to the forage value.

The negative marginal values of forage on the smaller representative ranches may be unfortunate, but not unreasonable. The marginal value of forage to society calculated here is not equal to the change in rancher's income from, say, a one AUM increase in forage. The interest and depreciation costs for breeding stock included as variable costs to derive the marginal value are real opportunity costs, but they are not necessarily out-of-pocket costs to the rancher. These costs range from 22 percent (for the 151 animal unit ranch) to 36 percent (for the 701 animal unit ranch) of total variable costs. The best guess of the actual change in the rancher's income for the 299 animal unit ranch, for example, is $10.53 minus 10.07, or $0.46 per AUM. Furthermore, the $12,000 cost of owner's labor (table 1) is not necessarily an out-of-pocket cost (many owners of small ranches hold outside jobs to supplement their income).

[6]*From a report to the U.S. Forest Service, Bureau of Land Management, and Colorado State Experiment Station by E. T. Bartlett, R. G. Taylor, and J. R. McKean of the Colorado State University Department of Range Science, titled "Impacts of Federal Grazing on the Economy of Colorado," August, 1979.*

Additional reasons exist which help explain the low returns to forage. Smith and Martin (1972) for example, interviewed a sample of Arizona ranchers and found most to be willing to accept low returns on their investment because of related benefits of owning and living on a ranch. And Martin and Jefferies (1966) concluded, "the relatively nonquantifiable outputs of farm fundamentalism and conspicuous consumption, as well as possibilities for the monetary outputs of tax shelters and ranch appreciation" help explain the prices paid for cattle ranches.

In applying the values to the future, the analyst may want to assume that the past real change in livestock values will continue in the future. In the absence of specific knowledge about the future, one is left with long term trends. Perhaps the most appropriate estimate of future price changes is the increase in real cattle prices over the past 100 years which has been 0.9 percent per year (estimated from Manthy 1978).

WATER RUNOFF

Water is a peculiar commodity which has received the attention of many writers, particularly in the arid West (see, for example, Kelso et al. 1974 and Young and Gray 1972). Pressures and opportunities for public investment in water-related facilities such as dams, irrigation systems, and drainage systems has given rise to a gradually unfolding set of federal regulations for planning such investment, beginning in the United

Table 3.—Allotments and permitted animal units on national forest land in the Salt-Verde Basin, 1977

	Allotment size in animal units (AU's)								
	0 to 190		191 to 349		350 to 585		586 to larger		Total
Forest	Number	Mean	Number	Mean	Number	Mean	Number	Mean	AU's
Kaibab	13	96	2	303	2	533	0	0	2,920
Coconino	35	76	8	268	5	432	3	666	8,962
Tonto	30	77	23	245	20	457	15	905	30,660
Prescott	8	111	6	273	0	0	0	0	2,310
Apache-Sitgreaves	14	104	3	273	1	439	0	0	2,714
Total	98	87	42	253	28	457	18	865	
Total AU's	8,562		10,626		12,805		15,573		47,566
AU's out of Basin	360		447		730		1,423		2,960
Total AU's in Basin	8,202		10,179		12,075		14,150		44,606
Percent of total	18		22		27		33		100

States with the Flood Control Act of 1936 and culminating, to date, with the Water Resources Council's Principles and Standards for Planning Water and Related Land Resources (1973) and the Procedures for Evaluation of National Economic Development Benefits and Costs in Water Resources Planning (1979). These documents provide useful guidance in developing planning guidelines for other resources. In addition, Young and Gray (1972) provide an excellent treatment of the economic value of water which should be consulted if the reader desires more detail than contained herein.

Market Characteristics

In Arizona, 89% of total water consumption is by the agricultural sector, with the remaining 11% consumed by the municipal and industrial sectors. However, the relative use by sector is not uniform across the state. The large population centers in the desert portions of the state are also the centers for most of the agricultural water use. Water use in many of the smaller cities and towns in cooler and moister portions of the state is almost entirely for municipal and industrial purposes.

The water market is not competitive. Some users pump water from their own wells. Elsewhere there may be a large number of buyers, but generally each buyer is dependent on only one seller. Supply of water in Arizona is dominated by municipalities, a few local public water developing organizations of water users (such as the Salt River Project), a few privately owned firms operating under public utility regulations, and individuals or business concerns that develop water for their own uses. The water supplying agencies are not owned by profit seeking firms. The self-supplying individuals and business concerns (typically farmers or miners operating their own wells or diverting water from streams) are single units, so they do not participate in any water market. The municipalities and organizations are users' cooperatives developing and supplying water for a specific group of users. Although water is a relatively homogeneous product and knowledge is adequate, the water supply structure assures a noncompetitive situation.

As will be explained below, the value of water can sometimes be derived from the value of agricultural products for which water is an input in production. The market for farm products is considered the best example of pure competition in the United States. There is a large number of buyers and sellers for most crops, entry to the market is relatively easy, products are relatively homogeneous, and knowledge about prices and production is adequate. In addition, the products produced from farm products, including meat (through feedlot operations) and various vegetable food stuffs, are exchanged in competitive markets.

Valuation

Several examples of valuation are presented here. Most are for runoff in the Salt-Verde Basin, which contains nearly one half of the national forest land in Arizona and is the watershed which provides the surface water supply for much of the Salt River Valley around Phoenix. Runoff from the Basin is controlled by the Salt River Project, which manages six dams and reservoirs and distributes water through several canals to farms, businesses, and homes in the Valley. Four of the dams produce hydroelectric power. The Project also manages numerous wells which pump ground water to augment the surface supply.

Let us assume for these examples that an alternative is being considered for management of forest vegetation which would increase runoff from certain areas, that on-site runoff quantities with and without the alternative are known, and that actual runoff quantities made available for downstream uses are known. Further, assume that runoff quality does not change with the alternative (step 1).

In addition to instream use by fish, wildlife, and livestock, as well as by humans for recreation, the water is used to produce electricity and consumed by the

agricultural, municipal, and industrial sectors downstream (step 2). The value in electricity production and in final consumption will be derived here (step 3).

Value in Electricity Production

The cost savings method is well suited to this situation, because the additional runoff would, in the Salt-Verde Basin, replace power produced by a more expensive alternative (step 4). The Salt River Project produces power both from the hydroelectric dams it manages and from plants using both oil and coal as fuel. Oil and coal are sold competitively. The oil, despite it's increasing cost, is important in handling peak demand periods. Power produced by the additional runoff could substitute for some of the power produced using oil, without affecting the total quantity of power produced. Figure 4 represents the savings assuming that 100,000 acre feet is the amount of the substitution only.

Based on an approximate 1977 oil price of $15.00 per barrel, and other costs of power production, increased runoff would have the following values if it passed through the following dams[7]:

Hydroelectric dams	Value of an acre-foot of additional water
Theodore Roosevelt	$4.50
Horse Mesa	6.00
Mormon Flat	3.00
Stewart Mountain	3.00

Thus, additional runoff flowing through all four dams has a 1977 gross value of $16.50 per acre-foot.

Oil prices nearly doubled between 1977 and 1979, and there is considerable uncertainty about future fuel prices. If oil prices rise high enough, one of two outcomes is likely: either new fuel sources will be developed (coal gasification or oil from shale, for example) or power plants will be modified to utilize coal to handle short-term needs such as peak electricity demands. These alternatives all involve significant costs, suggesting that the real value of additional runoff in power production should rise above the 1977 estimate.

Value at Point of Consumption—A Cost Savings Approach

The Salt River Project pumps ground water from nearly 250 wells in order to supplement the surface runoff supply. Additional runoff would replace pumped water, thus reducing operation and maintenance costs for some wells and slowing the rate of ground water depletion, making future pumping less expensive (step 4). Water from the least efficient pumps would be replaced first, so that the cost savings would decrease with increasing volumes of increased runoff. The estimated savings per acre foot for 1977 are:[8]

	Acre feet increment	Operation and maintenance	Reduction in groundwater depletion
1	25,000	$20.00	$1.60
2	25,000	16.50	1.53
3	25,000	16.00	1.44
4	25,000	14.30	1.37

Thus, the gross value of initial increases is estimated at $21.60 per acre foot. As with the power production example, figure 4 represents the cost savings assuming the quantity 100,000 acre feet represents only the replacement.

Value at Point of Consumption—A Change in Net Income Approach

The primary users in the Salt River Valley of any additional water from the Salt-Verde Basin are farmers. There is some unmet demand for water to irrigate feed grain and forage crops. All other, higher valued demands are already met and are always able to bid water away from the lower valued uses.

Most agricultural products, and most variable inputs used in the production of agricultural products, are sold in relatively competitive markets. Thus, it is appropriate to derive the value of irrigation water from the value of farm products using the change in net income method (step 4).

This application of the change in net income method is complicated by the multiproduct nature of the affected farms. Most farms receiving runoff from the Salt-Verde Basin produce a range of crops, from vegetables to cotton to feed grains and alfalfa, in order of decreasing value per acre. The exact combination of crops grown, and the acreage in each crop, will depend on available acreage, water availability and price, production costs per crop, returns per crop, water use per crop, double cropping and crop rotation possibilities, and the risk aversion of the farmer. Thus it has been common to model representative farms and use linear programming to allocate acreages to different crops given constraints on all relevant variables (for examples, see Hartman and Whittelsey [n.d.] and Kelso et al., 1973).

Figure 10, which depicts supply and demand curves for crop irrigation water in the Salt River Project based on a representative farm of 1,000 acres, is a 1977 update of similar schedules developed by Kelso et al. (1973) for 1966.[9] The supply schedule depicts the

[7]*Based on information provided by the Salt River Project, Phoenix, Arizona.*

[8]*Based on data provided by the Salt River Project, Phoenix, Arizona.*

[9]*From a report to the USDA Forest Service by William E. Martin and Gary B. Snider of the University of Arizona, Department of Agricultural Economics, titled "Valuation of water and forage from the Salt-Verde Basin of Arizona," September 1979, available from the Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona.*

variable costs to the farmers of different quantities of water available to the total farm acreage in the Project area. The demand schedule depicts the return to water and all fixed costs for different crops, and the acreage in different crops assuming water prices as shown on the supply schedule. The costs, returns, and water usages for each crop are listed in table 4. For example, wheat returns $24.03 per acre foot to water and fixed costs. If water cost rose to $24.03, farmers could not afford to grow wheat, even in the short run.

The demand and supply schedules intersect at a vertical section of the demand schedule, where total water use is 549,198 acre feet. Theoretically, up to 62,905 (612,103 minus 549,198) acre feet of additional water would be used, if available, to irrigate additional acreage, with each acre foot yielding a return to water and fixed costs of about $16.54.

As depicted in figure 10 by the horizontal segments of the supply curve, it is assumed that marginal and average variable costs of production are equal for each crop. Thus, the supply curve in figure 10 is that of the input water. The corresponding final product supply curve would also be horizontal over the relevant change in output, as is the supply curve for lumber in figure 5 for an increase from 5 to 6 MMBF.

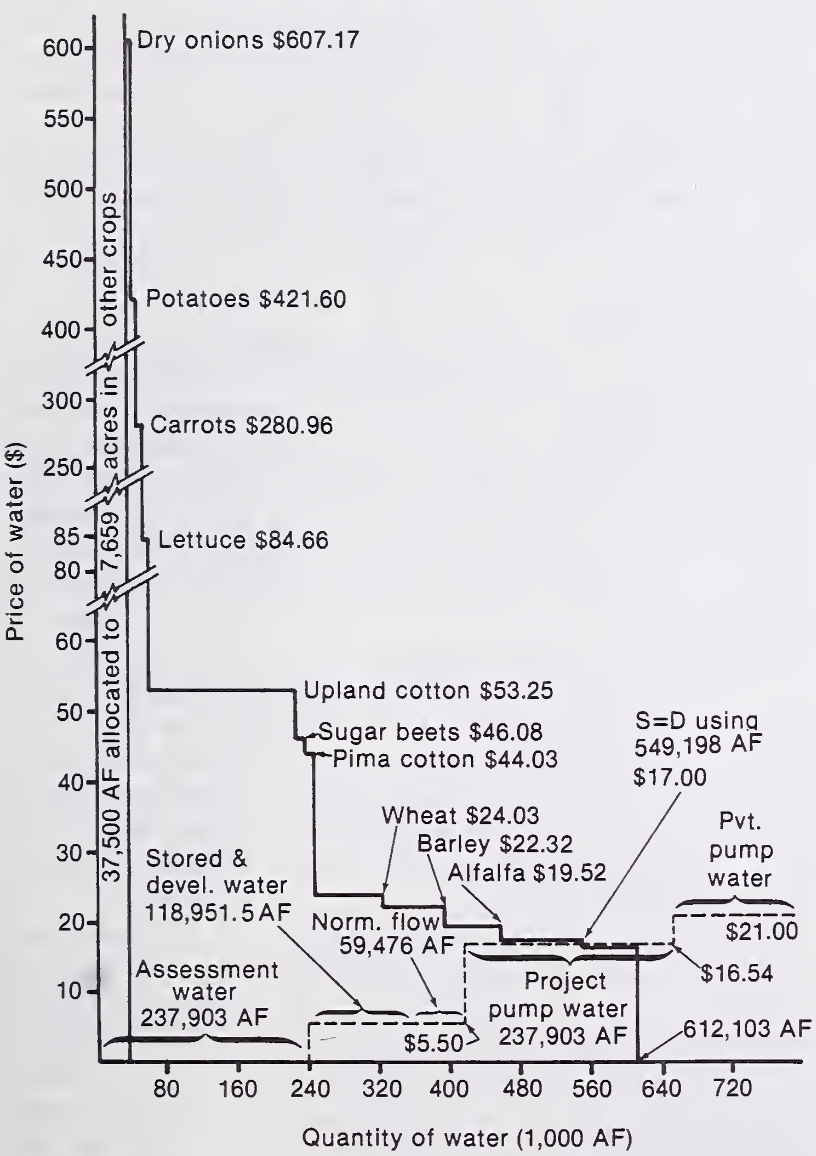

Figure 10.—Aggregate agricultural derived demand for and marginal supply of irrigation water, all farms, Salt River Project, 1977. From Martin and Snider's report "Valuation of water and forage from the Salt-Verde Basin of Arizona."

In reality, additional runoff would result in increased acreage planted only if the Salt River Project adjusted project pump water rates downward in response to the addition, or if all project pump water were replaced by runoff (essentially causing a drop in water rates for quantities above 420,000 acre feet). These two possibilities would each be depicted graphically by a new intersection of the demand and supply schedules in figure 10. However, such an outcome is unlikely for realistic increases. Nevertheless, the analysis depicted in figure 10 gives an approximation of the marginal value of water.

The modeling approach is very useful for estimating future values. Projections for the Salt River Project area[9] were based on assumptions about increases in pumping depth, future SRP water prices to farmers, and agricultural crop acreage. Total agricultural acreage was assumed to decrease in the future at a rate of 3 percent per year, which is the average annual decrease since 1965. Maximum proportions of the total agricultural acreage assigned to each crop were based on historical proportions and information about crop rotation needs and farmer's aversion to risk.

The projections for 1977 to 2015 are that the marginal value of water to the farmers, in 1977 dollars, rises to $19.20 in 1985, $19.52 in 1995, and remains at about that level to at least 2015. By 1995, project pump water would no longer be used by farmers, assuming continuation of current supplies of surface water. The relatively low cost of surface water would allow continued growing of field crops such as wheat and barley, which would be grown to reduce risk and provide crop rotation benefit. All high valued crops, including cotton and sugar beets, would use about 60 percent of total agricultural water, compared with 44 percent in 1977. Of course, one must not place too much weight on such projections. The past may not be a good guide to future rates of agricultural land conversion to future crop patterns. If the marginal use of water runoff changed, the value would increase significantly.

Sophisticated models are useful in estimating water values, as stated above, where affected farms produce several crops with different values and water use efficiencies. However, an estimate of at least the current water value is generally possible without using such models. The analyst must merely decide which crop or crops are the marginal crops in terms of return to water and fixed costs. In the Salt River Project area the obvious candidates are alfalfa, sorghum, and maybe barley. The net return to water and fixed costs per acre foot of water used is estimated, as stated above, by subtracting variable costs minus water cost per acre from returns per acre, and then dividing the return per acre by the acre feet of water used per acre following a source of farm budgets such as that developed by Hathorn and Farr (1977) for Maricopa County, which includes the Salt River Project. The net returns for alfalfa, sorghum and barley are $19.52, $16.54, and $22.31 per acre foot, respectively, in 1977 dollars (table 4). The marginal gross value of water may be assumed to be equal to the lowest of these — $16.54 per acre foot.

Table 4.—Summary of yields, prices, water use, and net returns per acre used in the model[1]

Crop	Unit	Yield	Price/Unit ($)	Gross returns ($)	Variable cost[2] ($)	Net returns ($)	Acre-feet per acre	Net return per acre foot
Pima cotton lint	lbs.	600	.90	540.00	355.43	220.13	5.00	44.03
Seed	tons	1.046	68.00	35.56				
Upland cotton lint	lbs.	1,100	.52	572.00	366.99	266.26	5.00	53.25
Seed	tons	1.750	70.00	61.25				
Wheat	cwt.	42.5	5.00	212.50	140.40	72.10	3.00	24.03
Grain sorghum	cwt.	36.0	4.25	153.00	103.39	49.61	3.00	16.54
Barley	cwt.	37.0	5.00	185.00	125.42	59.58	2.67	22.31
Alfalfa	tons	6.6	65.00	429.00	306.98	122.02	6.25	19.52
Sugar beets	tons	24.5	24.00	588.00	357.32	230.38	5.00	46.08
Potatoes	cwt.	300	9.00	2,700.00	[3]1,435.25	1,264.75	3.00	421.58
Lettuce	cwt.	275	7.00	1,925.00	[3]1,655.70	269.30	3.50	76.94
Carrots	cwt.	225	8.50	1,912.50	[3]1,210.10	702.40	2.50	280.96
Dry onions	cwt.	425	8.25	3,506.25	[3]1,684.78	1,821.47	3.00	607.16

[1]*Adapted from Martin and Snider's report "Valuation of water and forage from the Salt-Verde Basin of Arizona."*

[2]*Source: Hathorn and Farr (1977), adjusted to exclude the cost of water, to exclude fixed costs, and to include 5% of total variable costs as miscellaneous variable business overhead costs as did Mack (1968).*

[3]*Current complete vegetable crop budgets are not available. Budgets for 1966 (Mack) were adjusted in proportion to the rise in costs for field crops between 1967 (Mack) and 1977 (Hathorn and Farr). Variable costs have risen by a factor of 2.5.*

Another change in net income approach to valuing irrigation water, which applies where the change in water supply would cause changes in water use per acre rather than a change in acres irrigated, is to utilize irrigation water efficiency studies. Such studies show the change in yield per acre for different crops as more water is applied per acre while holding other inputs constant. The value of an additional irrigation is equal to the value of the increase in yield minus the costs of applying the additional irrigation (excepting the actual cost of the water).

Theoretically the rational farmer would use water in irrigating all crops so that the marginal values of water in irrigating each crop would be the same. However, various institutional and technical arrangements peculiar to the farming operation may preclude this. Thus, the analyst is wise to base such a valuation on examination of several crops.

Irrigation efficiency studies are not available for all crops in all locations, but such studies are available for some crops in major irrigation areas (see, for example, the bibliography in Anderson and Maass 1971). Crop response to irrigation is a matter of timing and quantity of irrigation water, as well as related timing and quantity of other inputs such as fertilizer. Some studies are more complete than others in their treatment of these relationships.

Ayer and Hoyt (1981) developed crop production functions for cotton, wheat, and sorghum on medium textured soils in Arizona, such as the Salt River Project area, based on several irrigation studies. Their production functions were sensitive to the quantities, but not the timing, of the inputs.

Use of their production functions to estimate the value of an additional acre inch of irrigation water, while holding all other variables at their mean levels, yielded a range of values.

For example, one additional acre inch of irrigation water, added to the 3 feet of water typically applied (table 4), on sorghum planted on medium textured soils will increase yields by about 30 pounds per acre. Based on our price of $4.25 per cwt. (table 4), the gross value of the increase in production is $15.30 per acre-foot. Subtracting the application (labor) cost of $6.73 per acre foot (Hathorn and Farr 1977), yields a net of $8.57 per acre-foot. For cotton and wheat, this approach yielded gross values of $31 and $0 per acre foot, respectively.

Thus, use of this approach suggests that the marginal value of water in irrigating the lower-valued crops (sorghum and wheat) is below $9 per acre foot, considerably lower than the values derived using the other approaches, where the number of acres irrigated is not fixed. It is reasonable to expect the value of more water added to an already irrigated acre to be less than the value of water used to irrigate a previously unirrigated acre.

Comparing the four estimates of marginal gross water value at the points of consumption, the cost savings approach yielded a value of $21.60 per acre foot. The two change in net income approaches based on increasing acreage per crop yielded a value of $16.54 per acre foot. And the change in net income approach based on increasing water use per acre yielded a value below $9 per acre foot.

Finally, what about future crop prices? Will real crop prices rise, causing real increases in residual water values, assuming the real costs of other inputs remain constant? In the absence of knowledge of the future, we can receive some guidance from past trends. Real prices of wheat and sorghum for grain have risen only slightly over the past century, and real prices of barley and hay have decreased slightly (Manthy 1978 table AP-5). Thus, the 1977 water value is a reasonable estimate of at least near future real values.

SUMMARY AND CONCLUSIONS

Monetary values can be useful measures of importance for public decision making. Where possible, monetary values are derived from market data. Such market-derived monetary values are a function of market institutions, externalities, advertising efforts, public good management decisions, the income distribution, and other factors which determine prices. The user of monetary values should be aware of the determinants of such values.

There is more than one monetary value for a given resource in a given situation. The correct derivation of monetary value depends on the use to which the value will be put. In land management planning, where decisions will be made about whether to change the quantity or quality of some product of the land, appropriate values are the changes in consumers' and producers' surplus.

Where the price of a product, needed in order to calculate the appropriate surplus measure, is not determined in a purely competitive market, techniques are sometimes available to estimate the price as if such a market existed. The most important prerequesites in estimating appropriate monetary values are an understanding of theoretical basis for the valuation and of the relevant markets. Often sufficient data or previous studies exist which, given these prerequisites, allow estimation of monetary values for land management planning in a relatively short time period. However, the user of such monetary values must be aware of the ever-present data problems associated with their estimation.

Additional problems arise in applying monetary values to management alternatives which span more than just the next few years. Two such problems are particularly important. First, future real prices are not known. Past changes in real prices may not be good indicators of future changes. Second, current prices, upon which estimates of surplus changes are based, are the result of innumerable private decisions made within the existing institutional framework of the economy. These prices are not necessarily appropriate weights for resource planning which affects future generations who have no say in today's market.

No matter how much effort goes into the valuation, it is usually best, and often necessary, to state a range for the required value, in addition to a best guess. This range should be used in the analysis of the land management alternatives. This is accomplished with sensitivity analyses to determine if the choice between alternatives depends on what value is chosen within the range. If it does, perhaps more effort is needed to more accurately specify the value.

Although using monetary values in public decision making has serious problems, it also has important benefits. The value of monetary values in decision making has been summarized well by Kenneth Boulding (1970, p. 129-130):

> Even though economic measurement may be abused, its effect on the formation of moral judgements is great, and on the whole, I believe, beneficial . . . We can grant, of course, that the . . . dollar . . . is a dangerously imperfect measure of the quality of human life and human values. Nevertheless, it is a useful first approximation, and when it comes to evaluating difficult choices it is extremely useful to have a first approximation that we can then modify. Without some guideline, indeed, all evaluation is random selection by wild hunches.

LITERATURE CITED

Anderson, Raymond L. 1961. The irrigation water rental market: A case study. Agricultural Economics Research XIII (2):54-58.

Anderson, Raymond L., and Arthur Maass. 1971. A simulation of irrigation systems: The effect of water supply and operating rules on production and income on irrigated farms. Technical Bulletin No. 1431, 82 p. USDA Economics, Statistics, and Cooperatives Service, Washington, D.C.

Ayer, Harry W., and Paul G. Hoyt. 1981. Crop-water production functions: Economic implications for Arizona. Technical Bulletin, 22 p. Agricultural Experiment Station, University of Arizona and U.S. Department of Agriculture, Natural Resource Economics Division, Economics Research Service.

Bator, Francis M. 1957. The simple analytics of welfare maximization. American Economic Review 47(3):22-59.

Baumol, William J. 1977. Economic theory and operations analysis. 626 p. Prentice-Hall, Englewood Cliffs, N.J.

Boster, Ron S., and Lester Davis. 1972. Soil-loss considerations. p. 243-250. *In* Watersheds in transition symposium: Proceeding. (Fort Collins, Colo., June 1972) Series 14, 405 p. American Water Resources Association, Urbana, Ill.

Boulding, Kenneth E. 1970. Economics as a science. 157 p. McGraw-Hill Book Company. New York.

Brown, Thomas C. 1981. Tradeoff analysis in local land management planning. USDA Forest Service General Technical Report RM-82. 12 p., Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Brown, Thomas C., Paul F. O'Connell, and Alden R. Hibbert. 1974. Chaparral conversion potential in Arizona. Part II: An economic analysis. USDA Forest Service Research Paper RM-127, 28 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Conklin, L. R., and R. A. Young. 1977. A method for estimating commodity prices for long-term farm planning. *In* Colorado Agribusiness Roundup, 25 p. Cooperative Extension Service, Colorado State University, Fort Collins.

Cory, Dennis C., and John Daubert. 1981. Evaluating direct benefit estimation procedures for irrigation projects: A simplified approach. Water Resources Bulletin 17(6):1066-1070.

Eisenman, Eric, Lee C. Wensel, Edward C. Thor, and Thomas W. Stuart. 1980. Economic data for wildland management in the western United States: A source guide. USDA Forest Service General Technical Report PSW-42, 125 p. Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.

Ferguson, Charles E. 1972. Microeconomic theory. 565 p. R. W. Irwin, Homewood, Ill.
Freeman, A. Myrick, III. 1979. The benefit of environmental improvements: Theory and practice. 272 p. John Hopkins University Press, Baltimore, Md.
Friedman, Milton, 1976. Price theory. 357 p. Aldine Publishing Co., Chicago, Ill.
Graaff, J. de V. 1957. Theoretical welfare economics. 178 p. Cambridge University Press, Cambridge, England.
Hartman, L. M., and Norman Whittelsey. n.d. Marginal values of irrigation water: A linear programming analysis of farm adjustments to changes in water supply. Technical Bulletin 70, 28 p. Agricultural Experiment Station, Colorado State University, Fort Collins.
Hathorn, Scott, Jr., and Charles R. Farr. 1977. Arizona field crop budgets, Maricopa County. 55 p. Department of Agricultural Economics, University of Arizona, Tucson.
Haveman, Robert H., and Burton A. Weisbrod. 1975. The concept of benefits in cost-benefit analysis: with emphasis on water pollution control activities, p. 37-65. *In* Cost-benefit analysis and water pollution policy. Henry M. Peskin and Eugene P. Seskin, editors. The Urban Institute, Washington, D.C.
Hirshleifer, Jack. 1980. Price theory and applications, second edition. 620 p. Prentice-Hall, Englewood Cliffs, N.J.
Kelso, Maurice M., William E. Martin, and Lawrence E. Mack. 1973. Water supplies and economic growth in an arid environment, an Arizona case study. 327 p. University of Arizona Press, Tucson.
Krutilla, John V. 1961. Welfare aspects of benefit-cost analysis. Journal of Political Economy 69(3):226-235.
Krutilla, John V., and John A Haigh. 1978. An integrated approach to national forest management. Environmental Law 8(2):373-415.
Maass, Arthur, and Raymond L. Anderson. 1978. ...and the desert shall rejoice: Conflict, growth, and justice in arid environments. 447 p. The MIT Press, Cambridge, Mass.
Mack, Lawrence. 1969. Economic implications of a dynamic land and water base for agriculture in central Arizona. Supplement to Ph.D. dissertation. File Report 68-2, Department of Agricultural Economics, University of Arizona, Tucson.
Manthy, Robert S. 1978. Natural resource commodities—A century of statistics. 240 p. John Hopkins University Press, Baltimore, Md.
Martin, William E., and Gene L. Jefferies. 1966. Relating ranch prices and grazing permit values to ranch productivity. Journal of Farm Economics 48(2):233-242.
Martin, William E., and Gary Snider. 1980. The value of forage for grazing cattle in the Salt-Verde Basin of Arizona. Report No. 22, 41 p. Department of Agricultural Economics, University of Arizona, Tucson.
Martin, William E., J. Craig Tinney, and Russell L. Cum. 1978. A welfare economic analysis of the potential competition between hunting and cattle ranching. Western Journal Agricultural Economics 60(12): 87-97.
Mayes, Horace M., Wesley Britton, and James F. Riggs, III. 1979. Arizona agricultural statistics. Arizona Crop and Livestock Reporting Service Bulletin S-14, 68 p. [A cooperative function of the U.S. Department of Agriculture Economics, Statistics, and Cooperative Service and the University of Arizona, Tucson].
McConnell, Campbell R. 1963. Economics: Problems and politics. 773 p. McGraw Hill Book Co., New York, N.Y.
Mead, Walter J. 1966. Competition and oligopsony in the Douglas-fir lumber industry. 276 p. University of California Press, Berkeley.
Menzie, Elmer L., and Thomas F. Archer. 1975. Cattle ranching in Arizona. Progressive Agriculture in Arizona. 27(4):1-14.
Niehaus, Robert D. 1978. Normalized prices for resource planning: A comparison of alternative. ESCS-39, 21 p. U.S. Department of Agriculture, Economics, Statistics, and Cooperative Service.
Ruderman, Florence K. 1978. Production, prices, employment, and trade in Northwest forest industries. USDA Forest Service quarterly reports. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.
Samuels, Warren J. 1972. Welfare economics, power, and property. p. 61-103. *In* Perspectives of property. G. Wunderlich and W. L. Gibson, editors. Institute for Research on Land and Water Resources, Pennsylvania State Univ., University Park.
Sassone, Peter G., and William A Schaffer. 1978. Cost-benefit analysis: A handbook. 182 p. Academic Press, New York, N.Y.
Smith, Arthur H., and William E. Martin. 1972. Socioeconomic behavior of cattle ranchers, with implications for rural community development in the West. American Journal of Agricultural Economics 54(2):217-225.
U.S. Department of Agriculture, Economics, Statistics, and Cooperative Services. Farm real estate market developments, Wash., D.C. [Published annually in August or September].
U.S. Senate. 1962. Policies, standards, and procedures in the formulation, evaluation, and review of plans for use and development of water-related land resources. 87th Congress, 2nd Session, Document 97, 13 p., Wash., D.C.
U.S. Water Resources Council. 1973. Principles and standards for planning water and related land resources. Federal Register 38(174):24778-24869, Part III.
U.S. Water Resources Council. 1978. Agricultural price standards. 11 p. Washington, D.C.
U.S. Water Resources Council. 1979. Procedure for evaluation of national economic development (NED) benefits and costs in water resource planning (Level C) and related land resources. Federal Register 44(102):30194-30258.
Young, Robert A., and S. Lee Gray. 1972. Economic value of water: Concepts and empirical estimates. 337 p. Final Report NWC-SBS-72-047, Colorado State University, Fort Collins. Prepared for The National Water Commission, Arlington, Va.

Brown, Thomas C. 1982. Monetary valuation of timber, forage, and water yields from public forest lands. USDA Forest Service General Technical Report RM-95, 26 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

This paper describes methods for deriving monetary values for three market products of the forest: timber, forage and water. Elements of the theory are reviewed and applied to actual forest conditions in central Arizona using available data. The paper should aid analysts with microeconomics training in understanding economic studies of resource values and in conducting valuations during the public land management planning process.

Keywords: Timber valuation, forage valuation, water valuation, public lands

Brown, Thomas C. 1982. Monetary valuation of timber, forage, and water yields from public forest lands. USDA Forest Service General Technical Report RM-95, 26 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

This paper describes methods for deriving monetary values for three market products of the forest: timber, forage and water. Elements of the theory are reviewed and applied to actual forest conditions in central Arizona using available data. The paper should aid analysts with microeconomics training in understanding economic studies of resource values and in conducting valuations during the public land management planning process.

Keywords: Timber valuation, forage valuation, water valuation, public lands

Brown, Thomas C. 1982. Monetary valuation of timber, forage, and water yields from public forest lands. USDA Forest Service General Technical Report RM-95, 26 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

This paper describes methods for deriving monetary values for three market products of the forest: timber, forage and water. Elements of the theory are reviewed and applied to actual forest conditions in central Arizona using available data. The paper should aid analysts with microeconomics training in understanding economic studies of resource values and in conducting valuations during the public land management planning process.

Keywords: Timber valuation, forage valuation, water valuation, public lands

Brown, Thomas C. 1982. Monetary valuation of timber, forage, and water yields from public forest lands. USDA Forest Service General Technical Report RM-95, 26 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

This paper describes methods for deriving monetary values for three market products of the forest: timber, forage and water. Elements of the theory are reviewed and applied to actual forest conditions in central Arizona using available data. The paper should aid analysts with microeconomics training in understanding economic studies of resource values and in conducting valuations during the public land management planning process.

Keywords: Timber valuation, forage valuation, water valuation, public lands

Rocky
Mountains

Southwest

Great
Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526